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Advanced Technology in the Canadian Food Processing Industry

John Baldwin, David Sabourin, Donald West

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These surveys focused on a set of technologies that apply to a wide range of manufacturing industries. In contrast, this survey focuses on the use of advanced technologies and business practices in a single industry—Canada's food-processing sector. This allows us to develop a finer degree of detail on the technologies being used in this sector. Previous work that focused on broad generic technologies found that food processing did not appear to be technologically advanced. When we use a more finely tuned body of technologies, which were developed with only this industry in mind, a different story emerges.

Not only does this study provide a picture of technology use at the plant level, but it also examines the way the industry's structure affects the use of technology and the performance of firms, including international competitiveness.

This study is the product of a joint research project between the Policy Branch of Agriculture and Agri-Food Canada and the Micro-Economics Analysis Division of Statistics Canada. John Baldwin supervised the project and helped write the final report. Donald West, formerly of AAFC and David Sabourin of Statistics Canada helped design the survey and write the final report. The survey was financed jointly by Agriculture and Agri-Food Canada (AAFC) and Statistics Canada. This project has been supported from its inception by Douglas Hedley and Zuhair Hassan at Agriculture and Agri-Food Canada. We owe Dr. Hassan a debt of gratitude for this support—for his help in designing the survey, for his extensive comments on this survey and for his support in bringing this report to publication.

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Preface

This study is part of a joint project of Agriculture and Agri-Food Canada and Statistics Canada, which has the following objectives:

1. To assess the level of technology use in the Canadian food-processing sector and its constituent industries;

2. To examine the demand for new technologies in relation to factors such as the need for new and better products, cost reduction and government regulation;

3. To examine the supply of new technologies in terms of domestic and foreign sources, and research and development effort;

4. To understand the process of technological change at the plant or firm level, including the methods used by plants or firms to identify technology needs and opportunities as well as impediments to change;

5. To assess the implications of technological change in food processing for the structure and performance of the food-processing industry, on the demand for products of Canadian agriculture, employment and investment.

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Highlights

1. This study investigates the use of advanced technology and business practices in the food-processing sector and in the individual industries that comprise it. It examines the factors influencing technology use—factors such as size of plant, country of control and stage of processing. In addition, it examines the relationships among technology use, business practices, business strategies and competitive environment. We also investigate the views of plant managers on the effects of advanced technology use on international technological competitiveness.

2. Information on the use of advanced technologies and business practices was obtained in 1998 using a survey of plant managers. Sixty-one advanced technologies in nine functional areas (processing, process control, quality control, inventory and distribution, management and information systems and communications, materials preparation and handling, pre-processing, packaging, and design and engineering) and 24 business practices in three areas (product quality, materials and distribution management, and product and process development) were identified in a detailed questionnaire. Included were questions on related topics such as plant and firm operations, strategies and competitiveness. The survey had an 84% response rate.

3. Decisions about the use of advanced technologies and business practices are an integral part of a firm's business strategies—strategies that reflect its competitive environment. Technology use is also influenced by plant characteristics such as size, country of control, products produced and production processes. In addition, we would expect the use of advanced technology and business practices to be interrelated.

4. *Competitive environment*—Firms in the food processing industry face a competitive environment that is dominated by several key problems—consumers can easily switch products, competitors are able to substitute across suppliers and new competitors are constantly emerging. As a result, competition is generally intense with respect to price, quality and service.

5. *Business strategies*—Firms react to price and quality competition by focusing special attention on their core markets, by both trying to maintain their cost competitiveness and by stressing quality. Technology use is seen primarily as a way of providing incremental improvements in quality, as well as cost reductions through productivity improvements.

6. The stress that is placed on quality pervades the operations of food-processing firms. Firms give greater emphasis to quality-related business strategies than to others. The effect of new technologies is perceived to be greatest in the area of quality improvement. Quality-related business practices are associated with a higher incidence of advanced technology use in many areas of the firm—from processing to packaging. The presence of these quality-related practices enhances the economic impact of technologies and the degree to which plant managers rank their firms as being competitive with foreign producers.

7. *Innovation*—Although food-processing firms concentrate on their traditional core markets, some 60% also stress the introduction of new products or the penetration of new markets. Over the 1995 to 1997 period, about 50% of plants made at least one major product innovation that did not involve a process change.

8. On the technology side, innovation is both incremental and consequential. While two-thirds of firms stress that their key technology strategy is an incremental one of improving existing technologies and processes, a little over 40% of firms indicated that they created new technologies and introduced innovations that involved only new processes.

9. *Technology use*—Almost 90% of plants use at least one of the advanced technologies identified in this study. Seven percent use 20 or more. Most plants use advanced technologies in several functional areas. As measured by the incidence of use, the areas of most importance are the key production areas—processing and process control, along with management systems and communications. Next comes packaging,

quality control systems and inventory and distribution. The area of least importance is design and engineering.

10. There are a number of exogenous or technical characteristics of plants that are related to technology use. In the first instance, plants that produce secondary rather than primary products are more likely to utilize advanced technologies in the core area—processing and process control. But they are also more likely to utilize advanced technologies in both the upstream and downstream areas. High-volume operations are not associated with greater use of the core processing area; they are more likely to use advanced technology in the upstream preparation areas and for process and quality control. Plants that focus on batch operations make greater use of the new management systems and communications technologies to control what is inherently a more heterogeneous production process, but otherwise are less likely to make use of advanced technologies.

11. Substantial differences in technology use are found between small and large plants. These differences are largest for the areas of management systems, design and engineering, and process control. The remaining areas all have differences as well. Some of these differences can be ascribed to differences in the type of operations done by small and large plants. Small plants are more likely to be doing more batch processing, with fewer high-volume products, and more likely to be concentrating on primary products. When these factors are taken into account with regression analysis, small firms are still found to use significantly fewer advanced technologies in the three areas of processing, process control and management systems, as well as in the downstream areas of inventory and distribution and packaging.

12. There are also significant differences in technology use between foreign- and domestically-owned plants. Foreign-controlled plants are more likely to use at least one technology, and more likely to use more than 10 advanced technologies. They are more likely to combine advanced technologies from different areas. They are more likely to use at least one advanced technology in each of the functional areas, with the exception of processing. When other characteristics such as size and type of operations are considered, foreign-owned plants are still found to be greater users of advanced technologies—but not in all areas. What distinguishes foreign-controlled plants from domestically controlled firms is their use of technologies in the areas of pre-processing, process control, management systems and communications, and design and engineering.

13. The causes of differences in technology use across small and large plants or between foreign and domestic plants cannot be traced to basic differences in managers' perceptions of the effect of the use of these technologies. After considering other characteristics that should influence economic impact, such as technology use, volume and batch operations, managers of foreign-controlled plants rarely report a greater economic impact. It is also the case that for many of the areas where there are significant differences in the use of advanced technologies between small and large plants, there are few differences in the economic impact derived from the use of these technologies by the two groups. Under the assumption that economic impact refers to the benefits of technology use, this means that it is the cost rather than the benefit side that primarily determines the differences in advanced technology use found in foreign and domestic, as well as in large and small plants.

14. The study also finds that the adoption of technology differs substantially across industries. The dairy, fruit and vegetable and "other" sectors lead. The fish, cereal and meat industries are in the middle and the bakery industry is last. These differences broadly follow differences in the competitive environment. Most of the traditional sources of competition are seen to be more intense in the fruit and vegetable and "other" industries. The dairy industry faces additional uncertainty as a result of rapid change in production technology. The results indicate that industries facing the most uncertain environment tend to be the most likely to use advanced technologies.

15. The connection between perceived competition and technology use can also be found within industries—between small and large plants. Large plants generally see their segment of the market as reflecting more intense rivalry, particularly in areas relating to new-product introduction. In keeping with this, large plants place greater stress on innovative activities and are more intense innovators. Concomitantly, they are more likely to use advanced technologies.

16. *Business practices*—The process of technological change involves both new machines and processes as well as specific business practices that often require organizational change. The study examined the use of business practices in three broad areas: product quality, materials and distribution management, and product and process development. The most commonly used practices are those primarily related to food quality and safety, especially good manufacturing practices, continuous quality improvement and acceptance sampling. They are followed by materials and distribution management practices, which are aimed more at productivity improvement. The most commonly used practices in this group are just-in-time inventory control and materials requirement planning. Finally, product and process development practices are the methods used to implement innovation and technology strategies; here, most plants use the practice of continuous improvement.

17. Quality-related practices are accompanied by the adoption of advanced technologies in almost all functional groups—from processing to design and engineering. So too are business practices aimed at product and process development. Materials and distribution management practices are positively related to technology use in process control, inventory and distribution, and management systems and communications.

18. *Effects of advanced technologies*—Since rates of technology incidence may be influenced by the arbitrary choice of technologies included within each category, the study presents alternate measures of importance—the evaluations of the economic impact of advanced technologies provided by food-processing plant managers. Here too, we find that processing, process control and management systems and communications are among the most important technologies. But quality control now moves to the head of the list, thereby reinforcing the importance of improvements in product quality as the primary objective of technology adoption in the food-processing sector. In the remaining functional areas, the downstream functions—inventory and distribution, and packaging—have a greater economic impact than the upstream functions—materials handling and pre-processing.

19. The economic impact ratings are positively influenced by the business practices employed, especially quality practices.

20. Specific economic effects that are perceived to be important include improvements in productivity, product improvement, and increased production flexibility, which are cited by some 60% of plants. In addition more than 70% of plants noted that the new technologies had improved food safety. Plants are about equally split on whether new technologies have given rise to a greater need for specific characteristics of raw materials—such as more consistent quality and timeliness.

21. *Technological competitiveness*—In addition to adoption rates and effects, this study gauges the importance of advanced technologies by their effect on international competitiveness. Twenty-three percent of managers believe their technology to be more advanced than that of their competitors in the United States, while 26% believe they are behind. The disadvantage is perceived to be greater with respect to European processors.

22. In considering their competitive position, managers give greatest weight to their capabilities in the area of processing, process control, quality control and pre-processing.

23. Large plants are more likely than small ones to believe that they are technologically competitive.

24. Industries that are the most intensive users of advanced technologies do not necessarily feel that they are more technologically competitive than their foreign counterparts. Indeed, exactly the opposite is the case. The dairy industry, which is one of the most intensive users, tends to rank itself behind, while the fish products industry, which is one of the industries least inclined to use the advanced technologies listed in this report, consistently ranks itself ahead of American producers. The meat industry, which is about average in terms of technology use, considers itself behind its U.S. competitors.

25. Examining differences in technology use across industries provides us with a wealth of detail about which industries have adopted more advanced technologies. As intrinsically interesting as these data are, they should not be misused. We should not equate higher technological incidence with being more competitive. The results of this study demonstrate that this would be wrong when comparing industries. Even if a Canadian industry such as fish processing does not

make intensive use of advanced technology, it may be ahead of foreign competitors that use even fewer of these technologies. Even if the dairy industry is one of the more intensive users of advanced technologies, it may still be behind its foreign competitors if they make even more intensive use of new technologies.

26. *Plans to upgrade technology*—Forty percent of plants in the food processing industry have firm plans to upgrade their technologies with new, more advanced technologies within three years. Plants that consider themselves to have the greatest technological disadvantage are the most likely to be planning major replacements (more than 25% replacement). Overall, however, technological differences are being perpetuated; those plants using the greatest number of advanced technologies are also the ones most likely to be planning upgrades.

Chapter 1 – Introduction

New technologies and business practices are key tools used by firms to improve their competitive position. Technological change results in better products and services, increased productivity, and the husbanding of scarce resources. Critical to international competitiveness at the national, sectoral, and firm levels, new technologies also contribute significantly to Canada's economic growth.

This study examines the importance of advanced technologies in the food-processing sector. Advanced technology is used in all parts of the production process of food-processing plants. In the early stages of pre-processing, it is used to assess and improve quality. During materials preparation and handling, it is used to manipulate and transport raw products. During processing, it transforms raw materials into final products with thermal and non-thermal preservation, separation and concentration methods, sometimes adding new ingredients to enhance safety and taste.

Advanced technology is used in process control to monitor the processing activity to regulate safety and quality. In quality control, it is used to assure final quality through process and product testing. Advanced communications systems are used to tie each step of the process together and provide operators and management with the information needed for timely intervention should it be necessary. Advanced technologies in the packaging area are used to protect food from spoilage before it reaches consumers and to facilitate handling. Advanced technologies that are used for inventory and distribution allow for the automation of the distribution process and the coordination of on-time delivery to customers through the use of bar-coding systems. Finally, advanced design and engineering technology allows computer-aided design systems to help design new processes.

While this study provides estimates of the degree to which plants in food processing make use of advanced technologies in the different stages of production, it also outlines the various factors that influence the degree of technology adoption. In doing so, the study focuses on differences in the technology regime between small and large establishments, between domestic- and foreign-controlled establishments and across industries within the food-processing sector.

The regime that determines technology is complex, and any assessment of the reason for sectoral differences must be multidimensional. Such an assessment must first recognize that the penetration of advanced technologies by sector will depend upon technological opportunity. Some processes will be more amenable to computerization than others. For example, it may be easier to mechanize a process that produces inanimate metal objects that are not easily bruised than a production process in food plants that involves vegetable and animal products. In addition, advanced technologies may be more easily adapted to processes in some industries than in others. For example, advanced computer-aided design and engineering systems have widespread applicability in the production process of automotive plants, but may be less applicable to designing new food products where knowledge of chemical and biological processes, as well as mechanical engineering systems, are important to the production process.

While these inherent differences condition the number and type of advanced technologies that will be used, to focus our explanation on these forces alone would be to adopt a model of technological determinism. There are other forces at work that influence technology use. These forces originate in the type of competition that governs an industry. The conditions in the food industry differ from many other industries, primarily because of the nature of the product produced. This product is referred to by economists as both a repeat and an experiential good. Because of the highly repetitive nature of the purchase decision, consumers are well informed about both the availability of substitutes and prices—more so than for irregularly consumed products like household durables. Because the satisfaction derived from the consumption of food depends so much on the sensory perception of consumers, quality and variety become important competitive tools for firms in the industry. But the intensity of both price and quality competition will vary across industries. Differences in competitive pressures should be reflected in differences in the rates of technology adoption and the types of technologies adopted.

Therefore, while this study focuses on technology use in the food-processing sector, it also examines the environment that the various industries face. This environment consists of the types of uncertainties facing firms that relate to the pressures exerted on them to adopt technology. On the one hand, these uncertainties stem from the intensity of market competition. Market competition is more intense where consumers can switch readily from one supplier to another, where new competitors are constantly arriving in the market place, and where imports offer a constant alternative source of competition to domestic production. On the other hand, the extent to which advanced technologies are being adopted will also be affected by the rapidity of advances taking place in the industry. Industries where technology is quickly becoming obsolete are also industries where there is greater pressure to use advanced technologies.

If we are to understand the climate that affects technology use, we must also investigate the types of business strategies that are being pursued. For example, industries may focus mainly on mature products and on cutting costs so that prices can be reduced. A price-reducing strategy requires technologies that increase productivity or improve efficiency. Alternately, firms may focus on non-price competition, where price is not an important competitive tool but where new products are. Industries may adopt an aggressive innovation strategy that focuses not only on introducing new products but also on developing new processes. The development of new processes often requires new, advanced technologies. Because of the importance of business strategy to technology use, this study examines the areas that receive the greatest emphasis and shows how these vary across industry sectors.

Technology use involves more than the use of specific new tools such as automated equipment. Defined more broadly, it also consists of the organizational formats that are adopted. These may simply involve practices that require the integration of different divisions. For example, making the best use of computer-aided design and manufacturing (CAD/CAM) systems requires the development of an appropriate interface between production and design and engineering divisions that facilitate such practices as rapid prototyping or concurrent engineering. Introducing advanced new technologies may also require that new equipment be used in specified ways if its advantages are to be fully realized. For example, quality control may require not only new technologies but also a formal total quality management system.

Because of this complementarity, this study not only investigates the extent to which advanced technologies are being used in the Canadian food-processing industry; it also examines the extent to which complementary business practices are employed in three areas. The three areas are: product quality, materials and distribution management, and product and process development.

A study such as this ultimately needs to evaluate the importance of technology use. In addition to measuring the incidence and intensity of technology use, we examine the economic impact of advanced technology implementation in two different ways. First, the study attempts to determine which technologies have the greatest impact, and second, it attempts to find out which specific effects, such as meeting regulatory requirements, quality improvement, or productivity gains, are most important.

Finally, the study uses a metric other than technology use to evaluate the state of the technological base of the Canadian food-processing sector. It examines the extent to which managers of food-processing plants rated their plants as competitive or non-competitive in relation to producers in the United States. Using these data, the study asks whether the industries that are the heaviest technology users are also the most competitive. Finally, the study examines which technologies and practices are behind the competitiveness ranking.

While previous studies have examined the role of advanced technologies in the manufacturing sector, this study is unique in that it focuses exclusively on the food industry. By doing so, this study provides much more detail than one that examines a broad range of industries.

Since the study focuses on advanced technology use, it begins with a brief review of the technological advances that are occurring in the food-processing industry in Chapter 2. Chapter 3 describes the survey used to obtain the data presented here. Chapter 4 outlines the structure of the food-processing industry. Chapter 5 describes the competitive environment and discusses how the product strategies used by the industry mesh with the industry environment. Business strategies are the topic of Chapter 6, which offers a broad overview of how technology and innovation strategies fit into the overall thrust of the

firm in five different functional areas: production, technology, human resources, marketing and management. Chapter 7 focuses on innovation, and in particular process innovation, and its relationship to the use of advanced technologies. Chapter 8 investigates business practices that complement advanced technologies. Chapter 9 examines technology use. The use of individual advanced technologies, as well as collections of these technologies (functional groups), are examined. The impact of new technologies on the operations and performance of firms is investigated in Chapter 10, while the factors determining a plant's international technological competitiveness are outlined in Chapter 11. Technology upgrades are discussed in Chapter 12. A summary and conclusion follows in Chapter 13. Appendices are included to provide complete answers to the survey and standard errors of these point estimates.

Chapter 2 – Technological Advances in the Food Industry

In general terms, the functions performed by food-processing plants are similar to those performed by other manufacturing establishments. Inputs must be obtained, stored, and then supplied to a manufacturing process that transforms them into a new product. New products are packaged, stored, retrieved and delivered. Manufacturing processes must be controlled to maintain product specifications, monitored for quality, and adjusted as required. As well, the overall operation must be managed.

There have been many recent technological advances in areas such as materials handling, inventory and distribution, and management systems and communications that have aided a wide range of industries, including the food industry. Typically, such advances involve the automation of these functions to increase efficiency and timeliness. Examples of some of these advances include bar-coding for product identification, robots for handling materials, and electronically controlled vehicles for moving products around the shop floor. Many of these technologies have been specifically adapted to the food-processing industry in order to deal with characteristics of raw, intermediate and finished food products that are related to perishability and form.

The principal feature that distinguishes food-manufacturing establishments from other manufacturing establishments is the type of processing activity they perform. Within the food industry, this activity differs by commodity and stage of processing—for example, a meat-slaughtering plant performs different functions than a flour mill or sausage plant. The technologies used in one food plant do not necessarily apply to others; however, a common feature of all plants is that they perform some type of product transformation. Primary or commodity processing often involves breaking down a raw product while secondary processing involves combining a set of ingredients. Most firms use some form of packaging. In addition, the end product must consistently meet high specifications, including those associated with quality and food safety.

Some basic food-processing technologies in use today originated thousands of years ago—drying, brining, smoking, cheese making, grain milling and baking. Others, such as canning, pasteurization, as well as drying and dehydration technologies were introduced in France in the 19th century. Still others are more recent developments, such as fast freezing, microwave cooking, orange juice concentration and vacuum concentration with essence recovery, which were all developed or introduced in the 1940s. More recently, other examples include vacuum-drying, freeze-drying and foam-mat drying, which came about in the 1950s; an explosive puffing process for fruits and vegetables and foam-spray drying, which were invented in the 1960s; and high-fructose corn syrup, the retort pouch and aseptic packaging, which were developed in the 1970s. Other new developments include the use of membrane technologies for the concentration and fractionation of liquids, and the use of irradiation for food preservation (see, for example, Greig 1984; Paulson and Wilson 1987; Fey 1987).

Few of these technologies are used today in their original form and advances are constantly being made in all areas. Technological advances most often result from adaptations and incremental improvements in existing technologies. These technological changes are not being made independently of changes that are occurring in the product market. The goal of the firm is to be competitive with respect to product value, that is, to create a price consistent with product quality. The development of new products, as well as products with more desirable characteristics, often involves the development or acquisition of new or improved processes.

Some technologies are aimed at improving the ability of the processor to respond to the immediate needs of buyers (such as wholesalers, retailers, food service operators, other food processors and, in the case of some by-products, other industrial users). These needs may include special formulations, or packaging and timely delivery. Meeting such needs requires flexibility in processing operations as well as effective inventory, distribution and communications systems.

More fundamentally, a key driving force behind technological change is consumer demand. In some cases, it is a matter of better meeting long-standing requirements for quality and safety. In others, it is a matter of responding to other market trends. Demand changes are related to increased income, changing demographics (such as changes in the ethnic and age composition of the population), changing employment patterns and lifestyles, and concerns about nutrition and food safety. The more important demand trends and examples of the industry's response are outlined below:[1]

Quality

Demand: improved flavour, texture, aroma and appearance; more natural; increased freshness.

Response: less intensive heating and minimal overheating; non-thermal preservation methods; natural flavours using encapsulation, and fermentation; improved packaging.

Nutrition

Demand: more healthy foods, including reduced levels of fats, sugars and salt, and more fibre.

Response: substitutes for fats, sugars and salt; special dietary foods; physical rather than chemical preservation; natural flavours, colours and additives.

Food safety

Demand: reduced danger of food poisoning; reduced risk of harmful ingredients such as carcinogens.

Response: elimination of food poisoning microorganisms from the most often contaminated foods and raw materials; improved, rapid and low-cost testing and handling procedures; substitution of safe for unsafe ingredients.

Convenience

Demand: ease of preparation; ease of storage; longer shelf life.

Response: products and containers suitable for microwave ovens; single-serving sizes; complete meals; flexible (pouch) packages.

Price or value

Demand: price consistent with product quality.

Response: more efficient use of labour, energy and materials; modified product formulations; automation; improved inventory management.

Among the most important recent technological developments are computer-based technologies, which have played a critical role in transforming the production process in the manufacturing sector (Baldwin and Sabourin 1995). Computer technologies have also affected the food-processing sector, permitting major changes in such areas as design, manufacturing, packaging, process control, quality control, materials and product handling, and management systems and communications.

Many of the technological advances in the industry have been associated with mechanization, remote control and automation.[2] Just as automation is a major means of achieving a plant's goals with respect to materials handling, inventory and distribution activities, it is also a key component in a more efficient and effective processing and packaging line. In this latter case, not only does automation apply to the online physical handling of materials and processes, it is also employed in processing and management control. Examples of key technologies here include sensors, vision systems, programmable process controls, statistical quality control, and computerized communications systems.[3]

Traditionally, automation has been applied to physical processes that cut costs and save labour—when used this way it is often called "hard" automation. However, more and more, leading firms have shifted their focus to improving process precision, that is, to ensuring that a process operates consistently according to specification. The focus has also been increasingly on using automation to improve product quality, or "soft" automation.

[1] Based in part on Gould (1996).

[2] Mechanization and remote control are "necessary steps on the way to automation". Mechanization is the replacement of manual operations with machines; remote control refers to the ability to monitor and adjust operations from a control panel; and "automation means that all actions needed to operate a process with optimal efficiency are ordered by a control system on the basis of instructions that have been fed into the control system in the form of a control program" (Dairy Handbook 1990, 320).

[3] For detailed descriptions of these technologies see, for example, Mittal (1997a) and The American Society of Agricultural Engineers (1990).

The overall objectives of automation are to reduce manufacturing costs, to create unique products of consistently high quality, and to ensure the flexibility needed to adjust to changing markets (Getchell 1987). More specifically, the goals include increased efficiency, the elimination of repetitive, monotonous and dangerous tasks, and the refinement of process control and quality control to more accurately meet consumer and regulatory demands. Automation can also provide detailed, real-time process and product information useful for management and research (Mittal 1997a, b, c).

Major advances in automation have arisen from computer-integrated manufacturing (CIM). After the Second World War, large manufacturing enterprises dealt with the increasing complexity of manufacturing processes and the limits of human information processing by organizing themselves along functional lines such as production, design, and inventory management. The automation of these units has tended to proceed independently, creating "automation islands" with differing hardware and software systems that are unable to communicate with each other. The CIM system was developed to link the functional areas using a common database and appropriate software (Nicolai 1997).

Some claim that the food industry has lagged behind other industries in introducing automation (Getchell 1987; Mittal 1997a, b, c). Reasons used to explain this lag include such factors as the perishability of raw and processed products; hygiene requirements; the heterogeneity of raw products and semi-processed ingredients; the large number of recipes; the need to detect and control product composition and product characteristics such as taste, texture and appearance; and the requirements of food safety. For example, maintaining product standards for composition and quality requires methods to monitor changes in these variables and the precise control of ingredients and processes, including the ability to make adjustments quickly.

Indeed, many processes in food processing are so complex that they are considered more of an art than a science. A necessary first step in implementing a control system is to obtain sufficient process knowledge to accurately define the control strategies. Mowery and Rosenberg (1989) have outlined the importance of simple measurement and quality control to innovation in the food-processing sector. This involves ingredient and process research as well as process modelling to capture the dynamics of the process (Getchell 1987). In cases where great precision is not critical or possible (such as with sensory attributes), soft computing techniques based on fuzzy logic can be used (Davidson 1997).

Technological advances are helping to overcome a number of these automation challenges. For example, analog computer control systems have replaced pneumatic control systems. The newer digital systems can respond quickly to correct problems. Also, programmable controllers and microprocessors have greatly reduced the "down time" associated with electromechanical controls, such as switches, relays, timers and solenoids.

Advances have also been made in robotics to create "arms" that can pick, place, transport and orient items in a similar manner to the human arm, but with more power, precision and repeatability. Machine-vision systems that can be used online to detect foreign material and to identify defects in colour, size and internal structure have also been improved (Mittal 1997b). Inline sensors for measuring process variables such as pressure, temperature, flow, moisture, colour and viscosity have been improved with advances such as solid state and chip technology (Mittal 1997c).

In summary, new products and processes are constantly being developed and introduced in the food-processing industry. This technological change is driven by consumer demands, particularly those dealing with exacting quality and safety concerns. A range of technological advances, some unique to the industry, are enhancing the industry's ability to meet the challenge of the new demands being placed on it. In the following sections, we examine what these technologies are and the forces that are driving the adoption of these technologies.

Chapter 3 – The Survey

To assess the technological prowess of the food-processing industry and the factors that influence it, this study uses the results of the 1998 Survey of Advanced Technology in the Canadian Food Processing Industry. Since this survey focuses on a single sector within manufacturing (food-processing), it investigates a much broader set of technologies than was possible in previous surveys covering the entire manufacturing sector.[4] These technologies are considered to be the newer, leading-edge technologies.

In order to make a preliminary identification of these technologies and the factors influencing their use, we reviewed the literature and met with experts in research establishments, universities, government and industry. The set of technologies selected is by no means exhaustive; the goal was to identify those technologies that were representative of the kinds of new technologies being adopted by the industry. It includes both those technologies applicable to manufacturing activities in general, as well as those more or less unique to the food-processing industry.

This information was then used to design a survey of food-manufacturing establishments. The survey is unique in its focus on the food industry and its comprehensive coverage of the industry.

The questionnaire consists of ten sections covering general firm and plant characteristics, the production environment, business practices, advanced technology adoption, skill development, development of new technologies, competitive environment, effects of technology adoption, impediments to technology adoption, and the importance of government programs in this area. General plant characteristics provide a profile of factors that are hypothesized to affect technology use—for example, whether the operations are continuous or batch, high or low volume. Business practices are investigated in three areas that are hypothesized to affect technology use—quality management, materials management and product development. Various aspects of the competitive environment—from consumer demand to the amount of technological change—are examined because of their potential effect on technological use. Different impacts of technological use—from productivity gains to enhancement of quality attributes—are investigated in order to evaluate the importance of technology use. Innovation, particularly process innovation, was also examined because of its close connection to the use of new advanced technologies.

For reasons that are discussed more fully in Chapter 4, we expected the rate of adoption of advanced technologies to be influenced by the type of products produced (the particular industry), the size of establishment and the nationality of ownership (country of control). The population was, therefore, stratified by these three variables. Four employment-size categories were used: 10 to 19, 20 to 99, 100 to 249, and 250 or more employees. Plants with fewer than 10 employees were not surveyed because of cost constraints. Seven industries (bakery, cereals, dairy, fish products, fruit and vegetables, meat and "other" food products[5]) and three ownership categories (Canada, the United States, and other foreign countries) were used. The population distribution of Canadian food processors across each of these three stratification variables is discussed in the next chapter as part of the industry overview.

[4] See Statistics Canada (1991), Baldwin and Sabourin (1995).
[5] The "other" food products industry consists of vegetable oil mills, sugar and confectionery, and other food products not elsewhere specified.

Table 3A: Survey Response Rates

Stratification Variable	Completed Units	Response Rate
Number of employees		
10–19	206	82.1
20–99	408	83.8
100–249	145	89.0
250 or more	95	81.2
Ownership		
Domestic	666	83.0
United States	108	85.0
Other foreign	80	90.0
Industry		
Bakery	129	80.6
Cereal	133	85.3
Dairy	105	86.1
Fish	110	82.7
Fruit and vegetables	101	89.4
Meat	137	85.6
Other	139	79.9
All	854	83.9

The survey was conducted in stages. First, each of the sampled units was contacted in order to determine the name and mailing address of the person who should receive the questionnaire. The questionnaire was then mailed out to the respondent, who was the plant manager, for the most part. Lastly, follow-ups were done by telephone interviews.

The sample was randomly drawn from a frame of Canadian food-processing establishments taken from Statistics Canada's Business Register. The survey unit was the establishment. Overall, 1,345 establishments were surveyed. The overall response rate for the survey was 84% (see Table 3A). Response rates were high across each of the three stratification variables—size, industry, and country of control—ranging between 80% and 90%. Response rates were 83% for small establishments; 89% for medium establishments; and 81% for large establishments.

Industry response ranged from a low of 80% for the bakery and "other" food products industries, to a high of 89% for the fruit and vegetable industry. Similarly, the response rate was 83% for domestically owned plants, 85% for U.S.-owned plants, and 90% for other foreign-owned plants.

For the purposes of this study, 61 advanced technologies covering nine functional areas were identified. The nine functional technology groups are: processing; process control; quality control; inventory and distribution; management and information systems and communications; materials preparation and handling; pre-processing; packaging; and design and engineering. Management systems and communications provide the integrative and control functions that serve to link the technologies used for each of the other purposes—from pre-processing through to distribution. The individual technologies in each group are identified in Table 3B. The functional areas and individual technologies are described in Chapter 9 on technology use. These and other food-industry technologies are described in such publications as those by Hui (1992), Greig (1984), McCorkle (1988), Heldman and Hartel (1997), Gould (1996), and Mittal (1997a).

Although the primary focus of this study is the entire food-processing sector, the results that deal with technology use at the level of the sector's constituent industries are also of interest, both in their own right and as a factor explaining the food-industry findings. As a result of differences in products, production processes and industry structure, we would expect the adoption rates for some advanced technologies to differ by industry. Reported rates may also have been affected to some degree by the specific technologies identified or not identified in the survey.

In some cases, the answers to questions about the importance of strategies, practices or effects are scored on a scale of 1 to 5, where 1 is not important and 5 is extremely important. Often, we summarize the answers to the questions that use these scales by reporting the percentage of establishments that report a score of 4 or 5. These are often referred to as extreme scores. Using these scores has several advantages. First, it provides the reader with an intuitive metric—the percentage of businesses that regard an item as very important. The extreme score also provides a robust indicator of the percentage of businesses that indicated they were above the midpoint in the distribution—for example those who felt that the innovation costs simply constituted a "significant" barrier to adoption—without worrying about distinctions beyond this point.

Unless otherwise specified, the data presented in this report are population estimates. They are reported as percentages of establishments affected, which have been derived by using the appropriate establishment weights to convert sample results to population values.

Table 3B: Advanced Technologies by Functional Group

Functional Technology Group	Advanced Technology
1. Processing	
1.1 Thermal preservation	– aseptic processing – retortable flexible packages – infra-red heating – ohmic heating – microwave heating
1.2 Non-thermal preservation	– chemical antimicrobials – ultrasonic techniques – high pressure sterilization – deep chilling
1.3 Separation, concentration, water removal	– membrane process – filter technologies – centrifugation – ion exchange – vacuum microwave drying – water activity control
1.4 Additives or ingredients	– bio-ingredients – microbial cells
1.5 Other	– electrotechnologies – microencapsulation
2. Process control	– automated sensor-based equipment – automated statistical process control – machine vision – bar-coding – programmable logic controllers – computerized process control
3. Quality control	
3.1 Process testing	– chromatography – monoclonal antibodies – DNA probes – rapid-testing techniques
3.2 Laboratory testing	– automated laboratory testing
3.3 Simulation	– mathematical modelling of quality or safety
4. Inventory and distribution	– bar-coding – automated product handling
5. Management and information systems and communications	– local area network – wide area network – inter-company computer networks – Internet—for marketing or promotions – Internet—for procurement, research, hiring, etc.
6. Materials preparation and handling	– integrated electronically controlled machinery – individual electronically controlled non-integrated machinery – electronic detection of machinery failure
7. Pre-processing activities	
7.1 Raw product quality enhancement	– animal stress reduction – bran removal before milling wheat – micro-component separation

Table 3B: Advanced Technologies by Functional Group – *Concluded*

7.2 Raw product quality assessment	– electronic or ultrasonic grading – collagen, colour or PSE probe – near infra-red analysis (NIR) – colour assessment or sorting – electromechanical defect sorting – rapid-testing techniques
8. Packaging	
8.1 Equipment	– non-integrated electronically controlled packaging machinery – integrated electronically controlled packaging machinery
8.2 Preservation	– modified atmosphere
8.3 Advanced materials	– laminates – active packaging – multi-layer materials
9. Design and engineering technologies	– computer aided design and engineering (CAD/CAE) – CAD output used to control manufacturing machines (CAD/CAM) – computer aided simulation and prototypes – digital representation of CAD output used in procurement activities

Chapter 4 – The Food-processing Industry

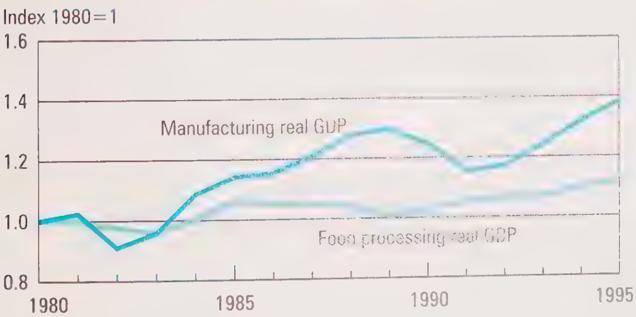
4.1 Industry Overview

The food-processing industry (SIC 10) is Canada's third largest manufacturing industry and consists of some 3,000 producing establishments. In 1995, the industry employed 210,000 people and accounted for about 11% of total manufacturing gross domestic product (GDP).

The industry has been growing at a modest rate; between 1990 and 1995, the value of shipments (in constant dollars) increased 12%, and manufacturing value added 8%. This compares with 29% and 10%, respectively, for the entire manufacturing sector.

The relatively slow growth of food processing extends a trend that began in the 1980s. In 1980, the food industry accounted for about 14% of the total gross domestic product produced by the entire manufacturing sector. Since that time, real output in the food-processing industry has only grown by some 0.7% per year, while the total manufacturing sector grew at three times that rate—or 2.1% per year. As a result, by 1995 the cumulative increase in the manufacturing sector was 38%, but the increase in food processing was only 11% (Figure 1). By 1995, the gross domestic product of the food-processing industry had fallen to about 11% of that of the manufacturing sector as a whole.

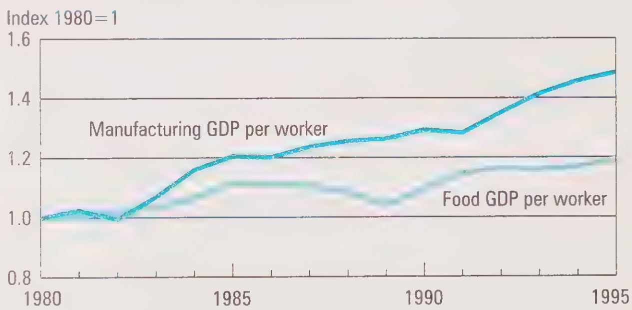
Figure 1 – Growth in Gross Domestic Product



Over this period, employment in the food-processing industry has remained stagnant. In 1980, there were some 225,000 jobs in the industry; by 1995, the number had fallen to about 210,000. This rate of decline was about the same for the manufacturing sector as a whole, where total jobs fell from about 2.1 million to about 1.9 million over the same period. As a result, food processing's share of employment in manufacturing stayed at about 11% over the period.

The lower rate of growth in food processing compared with manufacturing output, when accompanied by similar rates of change in labour inputs in the two sectors, results in lower growth rates of labour productivity in food processing. Real output per worker increased by only 1.1% annually in the food-processing industry in the period from 1980 to 1995, but it increased by 2.6% annually in the manufacturing sector as a whole over the same period. As a result, the cumulative increase in real GDP per worker over this period was 19% in food processing and 49% in manufacturing (Figure 2). There are also large differences in the growth of multifactor productivity, which increased by over 35% in the manufacturing sector between 1980 and 1995, but by less than 10% in the food sector.

Figure 2 – Growth in Productivity Per Worker

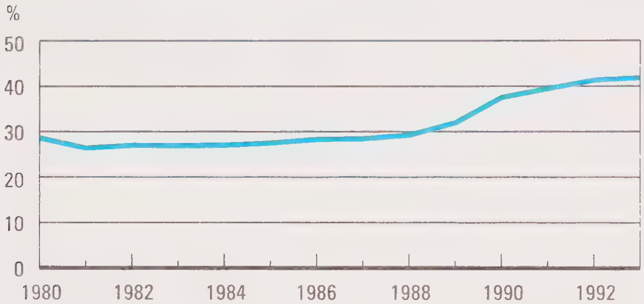


While the food-processing industry's links to the global economy (whether measured in terms of foreign ownership or trade) are not as strong as those of other industries in the manufacturing sector, the links of some of its constituent industries are strong enough to potentially affect economic performance. For the industry as a whole, exports and imports tend to be roughly equal; in 1995 they were both valued at about $8.2 billion. Exports represented some 19% of the value of shipments, and imports represented about 19% of the domestic sales of processed products. While food processing ranks lower than other manufacturing industries with respect to export intensity, since the late 1980s there has been a small upward movement of several percentage points. At the same time, import intensity has also grown, and the trade

balance (exports minus imports) has hovered around zero.

Foreign-controlled firms account for a relatively small percentage of establishments in the food-processing industry (11%) but these plants are larger than domestic plants; as a result, foreign-owned plants accounted for almost a third of total employment, and as of 1995, more than 40% of total shipments. The importance of the foreign sector has been growing in recent years. While establishments controlled from abroad accounted for about 30% of shipments in the early 1980s, this had increased to more than 40% by the early 1990s (Figure 3). The food-processing industry is also linked to the global economy through its use of imported inputs, including raw products and machinery and equipment. All the major food-processing equipment manufacturers are based in other countries.

Figure 3 – Foreign Share of Shipments



The food-processing industry is composed of a set of 22 four-digit industries. In this study, these industries are aggregated into seven major industry groups. In order to avoid confusion and excessive repetition, we will refer to the food-processing industry as a whole as "the food-processing sector" or "food manufacturing" or, most frequently, simply as the "food industry." In alphabetical order, the seven major industries that make up the food industry, as defined by their respective SIC 4-digit industries, are:

Bakery
- biscuits (1071)
- bread and other bakery products (1072)

Cereal
- cereal grain flour (1051)
- prepared flour mixes and cereal foods (1052)
- feed (1053)

Dairy
- fluid milk (1041)
- other dairy products (1049)

Fish
- fish products (1021)

Fruit and vegetable
- canned and preserved fruits and vegetables (1031)
- frozen fruits and vegetables (1032)

Meat
- meat and meat products (except poultry) (1011)
- poultry products (1012)

"Other" food
- vegetable oil mills (except corn oil) (1061)
- cane and beet sugar (1081)
- chewing gum (1082)
- sugar and chocolate confections (1083)
- tea and coffee (1091), dry pasta products (1092)
- potato chips, pretzels and popcorn (1093)
- malt and malt flour (1094)
- other food products (1099)

These industries differ appreciably with respect to the type of products they produce, the market structure, and the market conditions faced, including exposure to international markets. As measured by value added, the largest industry is the "other" category, at more than $4 billion in 1995. The next largest are the meat, dairy, and bakery industries at $2.9, $2.2 and $2.1 billion, respectively (Table 4A)[6]. The fish industry is the smallest with $1 billion of value added. On the other hand, when measured by employment, the meat industry is largest with 47,700 employees, and the "other" sector is next with 38,500 employees. The cereal industry has the lowest level of employment. The highest output per worker is in the cereal and "other" industries—and the lowest is in the fish products industry.

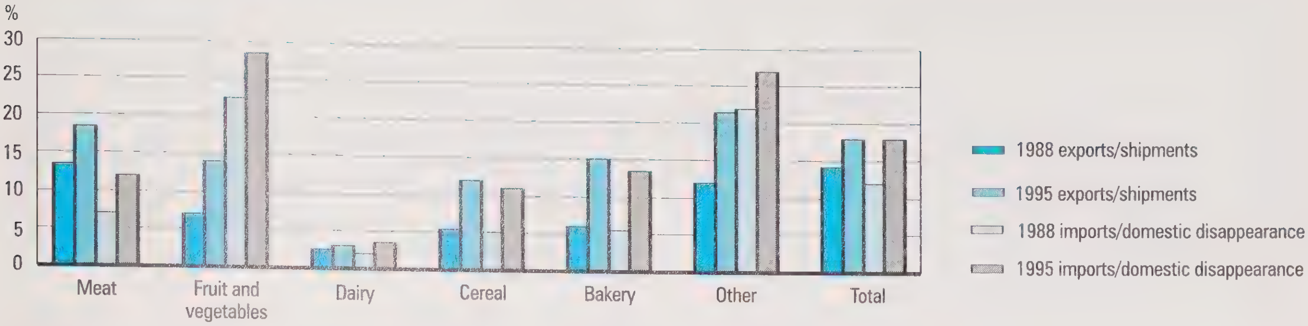
Table 4A: Industry Characteristics (1995)

Industry	Number of establishments	Total employment[1]	Total Value-added ($millions)	Average employment size	Value-added per worker ($100,000)
Bakery	552	27,040	2,060	49	7.6
Cereal	574	14,363	1,772	25	12.3
Dairy	376	21,728	2,198	58	10.1
Fish	430	21,640	1,076	50	5.0
Fruit and vegetables	237	18,141	1,980	77	10.9
Meat	604	47,702	2,917	79	6.1
Other	676	38,497	4,834	57	12.6
Total	3,449	189,111	16,836	55	8.9

[1] Excludes working owners and proprietors.

[6] These numbers are taken from the Survey of Manufactures.

Figure 4 – Export and Import Intensities



Note: The graph omits the fish industry, in which the export and import intensities are above 50%. It is, however, included in the total.

Of the more of 3,000 establishments in the food-processing sector, the largest numbers are found in the meat, cereal and "other" industries. Meat and "other" account for the largest number of employees. Establishment numbers are also relatively high in the fish products industry. But cereal and fish both have a smaller number of total employees and thus the smallest average establishment size. Average employment size is largest in the meat and fruit and vegetable industries.

Over the period 1990 to 1995, the fastest growing industries, as measured by value added, were the "other," bakery, and fruit and vegetable industries, while the fish and dairy industries declined. Relative growth rates, however, are much the same when measured by the value of shipments

The degree of import competition varies appreciably by industry segment. Import intensity is highest in the fish industry, where imports account for more than 50% of domestic disappearance (which is defined as shipments minus exports plus imports). The import intensity is higher than 25% in the fruit and vegetable industry and in the "other" industry. The import intensity is lower in the dairy, meat, cereal and bakery industries (Figure 4).

Exports have been a source of growth for all industries in the food-processing sector. Over the 1988 to 1995 period, the largest proportional increases in exports as a share of production occurred in the bakery and cereal industries. Exports are especially important to the "other" industry and the meat industry (Figure 4).

On the other hand, import intensity has also increased for all industries. The bakery and cereal industries had the largest proportionate increase in both import intensity and export intensity.

4.2. Characteristics Related to Technology Adoption

Previous studies have shown that the rate of technology adoption varies with the size of plant (Statistics Canada 1991; Baldwin and Sabourin 1995). Other factors relevant to technology adoption include the country of control, the plant diversification of the parent firm, the stage of processing, market structure, as well as other product or process characteristics (such as high-volume products, batch processing). Each of these is discussed here. Except where indicated, these characteristics are based on responses to the survey on the part of establishments.[7]

4.2.1 Distribution of plant size

While the average size of a plant in the food-processing sector in 1995 was 55 employees, we have already seen that average plant size differs substantially across industries (Table 4A). The data for Table 4A was taken from Statistics Canada's Survey of Manufactures and provide average levels of employment during the year. Because the number of employees in food-manufacturing establishments often varies greatly with the season, respondents to the Technology Survey were asked to indicate the maximum number of employees during the year. It was expected that if plant size were to influence the choice of technology, it would do so based on operating capacity. In fact, 40% of all qualified plants increase employment substantially to meet seasonal peaks. The five size classes used throughout this

[7] Note that in the survey only manufacturing establishments have been included (head offices are omitted). Establishments with fewer than 10 employees are excluded.

report—10 to 19, 20 to 49, 50 to 99, 100 to 249 and 250 or more employees—are based on the highest employment level during the year.

The largest percentage of establishments is found in the smallest size classes (Figure 5). About 24% of establishments have 10 to 19 employees; another 28% have between 20 and 49 employees. Only 10% have 250 or more employees.

Figure 5 – Establishment Size Distribution

The distribution of plant size by industry is presented in Table 4B. For most industries, the largest percentage of establishments is found in the smallest two size classes. However, the fish product industry is an exception; it has a lower percentage of plants in the lowest size category than most of the other industries, and more in the 100-to-249 size group. There is also a smaller than average percentage of dairy plants in the smallest size category. In contrast, there is a relatively larger percentage of establishments in the smallest class in the cereal industry. The highest concentration of plants in the 250-or-more size class is found in the fish, fruit and vegetable, dairy and meat industries.

4.2.2 *Country of control*

Multinational firms are described as having superior access to advanced technology (Blomstrom and Kokko 1997). The theory of the multinational firm stresses that expansion across national borders is related to the need to exploit hard-to-transfer skills that are related to marketing or technology (Caves 1982). This was confirmed by a survey of senior officials of multinational enterprises in the food industry (Vaughan et al. 1994; Vaughan 1995). These managers indicated that foreign production provided them with a greater ability to utilize, develop and protect intangible assets such as management and marketing expertise, brand names and technology.

In order to investigate the role of multinational enterprises in technological change in the food-processing sector, we stratified the sample by country of plant ownership or control. Three groupings were used: Canada, the United States and other foreign countries. These strata are based on the location of the head office of the controlling firm, that is, the firm that directly or indirectly holds a sufficient share of voting stock (typically 50%) to control its management.

Based on this survey, 89% of food-processing establishments are controlled by firms that have head offices in Canada; about 8% and 3% have head offices in the United States and other foreign countries, respectively.

The degree of foreign ownership or control differs appreciably by industry. The highest levels (around 22%) are found in "other" industries. On the other hand, less than 5% of all establishments in the meat and fish industries are foreign controlled (Figure 6).

Foreign control is positively related to plant size (Figure 7). For example, 25% of foreign-controlled plants have 250 or more employees compared with 9% of Canadian-controlled plants. The distribution of Canadian plants is skewed toward the smaller size classes; the distribution of foreign-controlled plants is skewed toward the larger plant sizes. Interpretations of the effects of foreign control and plant size

Table 4B: Distribution of Plant Sizes by Industry

	Employment size group				
Industry	10–19	20–49	50–99	100–249	250+
	percentage of establishments				
Bakery	25	29	24	17	5
Cereal	42	34	14	9	1
Dairy	17	28	25	15	16
Fish	2	27	22	32	16
Fruit and vegetables	26	22	17	20	14
Meat	26	29	16	14	15
Other*	25	26	19	20	9

* Includes Vegetable Oil, Sugar and Confectionary, and other SIC-E Industries.

Figure 6 – Foreign Ownership by Industry

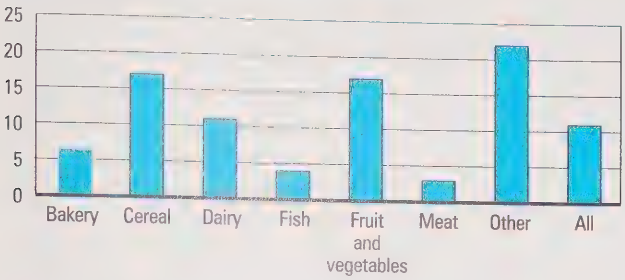


Figure 7 – Distribution of Foreign and Domestic Establishments by Size Class

on technology use need to take the relationship between these two characteristics into account.

4.2.3 Multi-plant firms and facility location

We would also expect the extent to which a firm is diversified to affect its ability to adopt advanced technologies. Holding plant size constant, one expects that belonging to a parent that has multiple plants means that a broader range of experiences are available in solving technology problems.

Multi-plant firms have more opportunities for specialization, and, at the same time, are more likely to force certain types of management and communications problems, all of which affect the need, as well as the opportunity, to introduce advanced technologies at the plant level. To capture this effect, we measured the extent to which each plant belongs to a multi-plant firm.

On average, 39% of all plants are a part of a multi-plant firm. This is a characteristic that is strongly related to plant size; while it applies to only 15% of plants with 10 to 19 employees, it applies to 89% of plants with 250 or more employees (Figure 8).

Figure 8 – Percentage of Plants Belonging to Multi-plant Firms

4.2.4 Stage of processing

Technology use is also thought to depend on whether a plant is engaged in primary processing (that is, the first stage of processing where raw products are processed to produce fresh meat, flour, fluid milk, cheese, canned fruit and frozen vegetables), or secondary, value-added processing (the further processing of primary products to produce products such as sausages, frozen dinners and baked goods), or both. For instance, the use of advanced packaging applies less to the early stages of the production process than to the later stages.

Plant managers were asked to categorize their operations as primary processing, secondary or both. The line between the two depends on how managers interpret the difference between the two and this may vary by industry. For example, in bakery products, managers may classify bread as involving nothing more than primary processing and think of more complex products as secondary.

Overall, 39% of establishments are engaged in primary processing only, 22% are engaged in secondary processing only, and 39% do both (Table 4C). This means that about 80% of establishments in the food industry do at least some primary processing, and 60% do at least some secondary or further processing.

As might be expected, the percentage of plants engaged in each type of processing varies by industry (Table 4C). Establishments in the fish, dairy, and bakery industries are the most likely to specialize in primary processing. Plants in the bakery and "other" industries are the most likely to specialize in secondary processing; while plants in the fish and meat industries are the most likely to do both primary and secondary processing. Very few bakery plants combine primary and secondary processing within their operations.

Table 4C: Selected Establishment Characteristics by Industry

Establishment characteristics	Bakery	Cereal	Dairy	Fish	Fruit and Vegetables	Meat	Other*	All
	percentage of establishments							
Stage of processing								
Primary only	50	34	53	43	38	36	27	39
Secondary only	35	22	14	9	25	18	30	22
Primary and secondary	15	44	33	48	36	46	43	39
High-volume products	54	61	71	73	69	62	55	62
Operations								
Continuous	59	39	65	57	45	62	45	53
Batch	41	61	35	43	55	38	55	47
Number of competitors								
None	3	1	1	4	4	6	2	3
1–5	30	15	24	15	34	19	35	24
6–20	26	37	28	31	42	39	44	36
More than 20	41	48	47	51	19	36	19	37

* Includes Vegetable Oil, Sugar and Confectionary, and other SIC-E Industries.

Plants with 10 to 19 employees tend to be concentrated in primary processing (46%), while those with 250 or more employees are the most likely (58%) to produce both primary and processed products. The proportions for all the other size groups approximate the average for the entire food-processing sector.

There are no notable differences between domestic- and foreign-controlled firms with respect to their likelihood of engaging in the different types of processing.

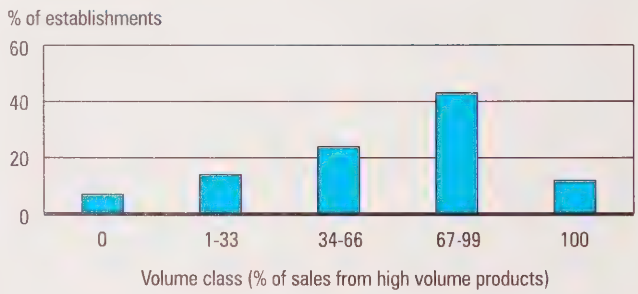
4.2.5 Other product and process characteristics

Other product or process characteristics that might be expected to influence technology use include whether a firm produces high-volume products or short runs of several different products, and whether a firm uses continuous or batch operations. Technology use and business practices are also likely to be related to a plant's food regulatory regime.

Volume products. The production of high-volume products may create a need for flexible manufacturing systems and may affect the type of materials handling and inventory control systems used. The fixed costs of some of the technological processes examined in this study may simply be too high to permit their introduction by firms with relatively low volumes. On the other hand, firms with low volumes may require "flexible" technologies to facilitate quick changeovers between product lines.

About 50% of establishments indicated that high-volume products represent two-thirds or more of all their shipments (Figure 9). Another 25% said that high-volume products accounted for between one-third and two-third's of their shipments.

Figure 9 – Distribution of Plants According to Volume Class



Large plants are more likely than smaller plants to have more of their output in high-volume products. Canadian-controlled plants are more likely than foreign-controlled plants to have more than two-thirds of their output in high-volume products.

The importance of volume shipments differs substantially across industries. Firms in the fish, dairy, as well as fruit and vegetable industries reported that roughly 70% of their shipments involve high-volume products. At the other end of the spectrum are the bakery industry and "other" specialty sector, where volume is much less important (Table 4C).

Continuous operations. The extent to which operations involve continuous production flows or batch processes is related to the volume characteristics of the production process. Some processes, such as traditional breadmaking, are inherently batch operations. It is difficult to establish continuous operations in plants where there are short production runs. Plants that produce numerous products require a production process that continuously changes product lines and focuses on individual batches. It is expected that the technologies required for each type of process differ—much as they would differ for high- and low-volume product lines.

Only 53% of establishments have continuous operations (Table 4C). This means that almost one out of two plants have a production line that involves some degree of batch operations. Interestingly, Canadian-controlled plants are more likely to focus on continuous operations than foreign-controlled plants—54% and 41% respectively. This may indicate that multinational firms focus more on product lines that involve product differentiation and batch operations. The percentage of establishments reporting continuous operations increases with plant size—from about 40% of establishments in the 10-to-19 size class to more than 64% in the largest size class (Figure 10).

Figure 10 – Percentage of Establishments with Continuous Operations

Industries differ substantially in their use of continuous processes for production (Table 4C). At the head of the list are dairy and meat. The cereal, fruit and vegetable and "other" industries are below the sector average when it comes to utilizing continuous operations and above average in terms of batch processes.

Regulatory regime. All food-processing plants are subject to the food health and safety regulations of the markets they serve. About 80% of food-industry plants undergo federal inspection, 50% provincial inspection, and 25% local inspection (see Appendix A). The means used by a plant to meet these regulations are related in part to the technologies and business practices employed in the plant.

4.2.6 Markets and competitors

One might expect market location to influence the technology used by plants. Firms active in foreign markets, for example, might be expected to use more sophisticated distribution and communications technologies. These differences in market location are related to differences in plant characteristics such as size, country of control and types of products produced.

Plants in the food-processing sector serve more than one geographic market. About 80% serve regional Canadian markets, 50% serve national Canadian markets, 47% serve U.S. markets, and 36% serve other foreign markets (see Appendix A).

The number of competitors that plants face varies considerably. Slightly more than a quarter of plants (27%) have a small number of competitors—five or less (Table 4C). The rest of plants are split quite evenly; 36% have a medium number of competitors (6 to 20) and 37% have a large number of competitors (more than 20).

Foreign-controlled enterprises face fewer direct competitors than Canadian-controlled enterprises. Over 40% of domestic establishments compete against more than 20 firms while only 22% of foreign-controlled firms do so. In contrast, 40% of foreign-controlled establishments compete against fewer than six firms, while only 25% of Canadian-controlled firms do so. Thus, not only are foreign firms more specialized, they are also more likely to operate in relatively concentrated markets.

There is no consistent pattern evident in the number of competitors across class sizes (Figure 11). The smallest and largest size groups tended to identify more competitors than the other size groups. The percentage of firms facing between 6 to 20 competitors increases across size classes—from 24% in the 10 to 19 group to 41% in the 250 or more employee group.

While the majority of establishments in all industries face more than six competitors, there are some differences in the competitive environments faced by each industry. Firms in the bakery, "other," and fruit and vegetable industries are the most likely to have five or fewer competitors (Figure 12). The cereal and fish industries have the largest percentage of plants that face more than six competitors.

Figure 11 – Distribution of Number of Competitors by Size

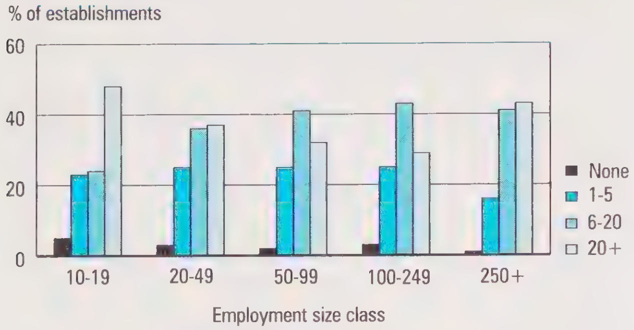
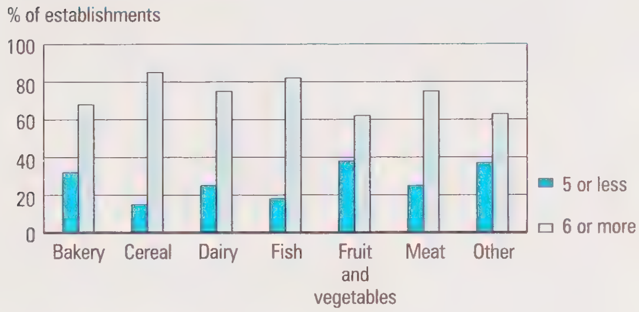


Figure 12 – Distribution of Number of Competitors by Industry



4.3 Summary

The food-processing industry is one of Canada's largest manufacturing industries. Its constituent industries produce products ranging from frozen dinners to animal feed. On the whole, the industry consists of modest-sized plants whose output and productivity have been growing at a moderate rate since the early 1980s. The participation of multinational firms in the industry has also been growing, and its trade exposure, which is still low compared with most manufacturing industries, has been increasing.

The following chapters discuss the use of technology and innovation, as well as related business practices, found in the food industry. Because of the inherent interest in differences in technology use across plant-size classes, between multinational and domestic firms, and across industries, we will consistently provide evidence of differences in technology use across these classes. This chapter has provided background information on the differences in plant characteristics by size class, industry and country of control.

Overall, small plants are more likely to be owned domestically, to do less processing of a continuous nature, to have smaller proportions of shipments that are high-volume products, and to face a larger number of competitors. They are also more likely to focus on primary processing and less likely to combine both primary and secondary processing. Finally, larger concentrations of small plants are found in the cereal, bakery and meat industries.

Foreign-controlled plants are likely to be larger and to be found in the cereal, fruit and vegetable, and "other" specialty sectors. They are more likely to belong to a firm that has multiple plants. They are just about as likely to be involved in primary processing as domestically owned plants. They are less likely to have a larger percentage of shipments in high-volume products, which indicates less specialization and more product diversification. They are also less likely to have continuous operations.

We have also noted considerable differences in structure and performance across the industries studied here—fish, fruit and vegetables, dairy, cereal, bakery, meat and poultry, and "other." The fish industry, which is large in terms of total shipments, faces the highest import intensity. This industry has one of the highest percentages of firms engaged in primary processing, and has a low level of foreign ownership. Average employment in a fish-processing plant is lower than the sectoral average. Fish plants tend to focus either on primary processing or a combination of primary and secondary processing. Fish products have relatively high-volume operations and face a relatively large number of competitors. Fish product plants have the lowest output per worker of all the sectors.

The "other" industry and the fruit and vegetable industries are also quite large overall; they have larger than average plant sizes and higher than average import ratios, as well as one of the higher levels of foreign control. This would indicate that they are more likely to operate in oligopolistic markets where there are five or fewer competitors. Both of these sectors have a high output per worker. The "other" industry does the lowest amount of strictly primary processing and focuses more on combined secondary and primary processing; it also has the least shipments of high-volume products, and places the greatest stress on batch rather than continuous operations.

The fruit and vegetable industry does considerably more primary-only processing than the "other" industry and has a relatively high volume, but is also above average in stressing batch operations—probably because of product variety. Nevertheless, establishments in the fruit and vegetable industry are split

about equally between those that do primary processing only and those that do combined primary and secondary processing. They do so in about the same proportions that characterize the industry as a whole.

The cereal industry also has one of the highest levels of foreign control, but is relatively small overall and is characterized by smaller establishments. The cereal industry does less primary processing than average and more combined secondary and primary processing than average. Similar to the "other" industry, the cereal industry produces final differentiated products that have more value added. Cereal industry firms tend to be about average when it comes to high-volume operations but are significantly above average in terms of adopting batch processes. They have one of the highest output-per-worker values of all the industries. Firms in this industry tend to face a relatively large number of competitors.

The meat and dairy industries are large, with a large average plant size and low foreign control. The dairy industry has the highest percentage of plants engaged in primary processing, but its output per worker is higher than the sectoral average. Firms in this industry are more likely to face a greater number of competitors than those in other industries. The meat industry, on the other hand, is average with respect to the percentage of plants that specialize in primary production but slightly higher than average with respect to the percentage that engage in both primary and secondary processing. The meat and dairy industries are the most likely to have continuous production—although the dairy industry is above average in stressing high-volume products, and meat is just average. The meat industry has a relatively low output per worker.

The bakery industry is one of the smallest industries with respect to output but it employs large numbers of people. It has an average plant size that is less than the food-industry average and an output per worker that is also lower than average. It has the highest proportion of plants that specialize in secondary processing. It also gives the least importance to high-volume products and is more likely to function in oligopolistic markets where there are five or fewer competitors.

Chapter 5 – Competitive Environment

The competitive environment influences the rate and type of technology that firms adopt. The nature of competition is determined by characteristics of the product market, the production process and the structure of the market.

Food products have several important characteristics that influence the nature of competition in the industry. First, because they tend to involve continuous, repetitive purchases, they give consumers considerable information. Consumers continually acquire price information on regular shopping trips and, as a result, can respond quickly to price differences that emerge. Second, the quality of food products receives continual scrutiny, both because of safety considerations and because the consumption of food is so closely related to the gratification of the senses (taste, smell). Third, the wide range of choices that are available to satisfy the needs of consumers means that most products (from meat to dairy to vegetables to processed foods) compete directly against one another for the food budget. These three aspects of the food market mean that consumers are constantly evaluating price/quality trade-offs across a wide range of products, and that there is intense competition with respect to price and quality in most submarkets.

These characteristics of the competitive environment are reinforced or attenuated by other market characteristics such as the significant presence in some segments of a small number of firms with strong brands, government regulation and import competition.[8] At the same time, many processors face large food retailers, wholesalers, and food-service firms as buyers. Some of these have their own processing operations. As described in the industry overview, both import competition and export opportunities for food products are increasing. These trends emphasize the importance of being internationally competitive. At the same time, regulations in areas such as advertising, packaging, labelling and food safety must be met.

Firms must develop competencies to deal with the problems posed by this environment. We would, therefore, expect differences in the type and intensity of competition to influence the strategies that are adopted and the emphasis that is placed on using advanced technologies. For example, firms in industries where products quickly become obsolete because of technological change or because of shifting consumer preferences must emphasize the development of new products. Firms in industries where technology quickly becomes obsolete have to master process innovation if they are to survive. Understanding the types of competitive environments faced by firms in different industries in the food sector is therefore critical to understanding the strategies employed.

Two key characteristics of the competitive environment are the uncertainties of market forces facing food-processing firms and the forms of product competition that firms adopt. Each of these will be discussed in turn.

5.1 Uncertainty and Market Forces

Characteristics of the market that create uncertainty and that influence the competitive behaviour of firms include the ease of entry from various sources, import competition, difficulties in predicting consumer demand, and the rapidity with which products and technology become obsolete. Higher rates of entry are associated with more intense competition in a number of ways (Baldwin 1995). Uncertainty of demand makes tacit collusion in oligopolistic markets more difficult. Rapid technological change places intense pressure on existing firms and often erodes the advantages of incumbent firms.

In this study, managers were given a scale of 1 to 5 (where a score of 1 indicates strong disagreement, 3 indicates neutrality, and 5 indicates strong agreement) to rate the extent to which eight different sources of uncertainty affected their industry. Managers indicated whether: 1) imports offered substantial competition; 2) consumer demand was difficult to predict; 3) competitors actions were difficult to predict ; 4) the arrival of new competitors was a constant threat; 5) product obsolescence was rapid; 6) production technology changes rapidly; 7) competitors could easily substitute among suppliers; and 8) customers

[8] For a more detailed description, see *The Canadian Food and Beverage Processing Sector* (Agriculture and Agri-Food Canada, 1998).

Table 5A: Uncertainty of Competitive Environment by Industry

Sources of uncertainty	Bakery	Cereal	Dairy	Fish	Fruit and vegetables	Meat	Other	All
	percentage of establishments reporting a score of 4 or 5							
Imports offer substantial competition	20	25	30	45	55	43	52	38
Consumer demand is difficult to predict	43	40	40	46	38	37	34	40
Competitors actions are difficult to predict	33	41	50	38	45	34	41	39
The arrival of new competitors is a constant threat	49	44	56	55	52	49	56	51
Products quickly become obsolete	18	13	12	15	21	11	24	16
Production technology changes rapidly	35	26	53	31	37	39	30	35
Competitors can easily substitute among suppliers	52	45	62	53	55	44	48	50
Customers and/or suppliers can become competitors	51	46	45	55	49	45	40	47

and/or suppliers could easily become competitors. The percentage of establishments reporting scores of 4 (agreement) and 5 (strong agreement) for each of these factors is provided in Table 5A.

Overall, the threat of increased competition from new competitors—that is, the threat of customers or suppliers becoming competitors, the ease with which competitors can easily switch among suppliers, and the threat offered by new entrants—are the areas of greatest uncertainty. About half of managers consider these problems to be severe. The predictability of consumer demand, the predictability of competitors' actions, the competition from imports and changes in production technology are next in importance. The lowest percentage of managers are concerned with product obsolescence.

Differences exist in the competitive environments faced by the seven industries studied here. Four different groupings are evident. The bakery and cereal industries make up the first set. Managers in these industries stress that the areas of greatest uncertainty are the threat of new competitors, the concern that customers or suppliers can become competitors, and the ease with which competitors can substitute among suppliers. Other causes of uncertainty are given less emphasis.

In the second group, the fish and meat industries, managers also place the greatest emphasis on these three sources of uncertainty, but they are more concerned about imports than the first group.

In the third group, the fruit and vegetable and "other" industries, managers place the same high degree of emphasis on the threat from new competitors, supplier substitutability by competitors and the ability of suppliers or customers to become competitors, while being even more concerned than the second group with the threat of import competition.

The dairy industry exhibits yet a fourth pattern. Like all the other industries, managers here rank supplier substitutability and the threat of new competitors as the most important sources of uncertainty, but unlike the others, they rank rapidly changing production technology third. Firms in this industry, therefore, have a special need to develop an effective technology strategy in order to compete.

5.2 Nature of Competition

The type of risks that a firm faces affects the product market strategies it adopts as it struggles with the uncertainties that arise from its competitive environment. Firms can compete in a number of ways—through new products, improvements in quality, and lower prices. Some firms will try to develop a competitive advantage by producing the same "good" at a lower cost than its rivals. Others will rely on exceptional customer service. Firms may use a combination of these and other strategies. The outcome of the choices made here determine the key areas of market competition and, in particular, how technology will be used to support a firm's objectives.

Plant managers rated the intensity of competition in their industry in a number of areas: price, product quality, customization of products, flexibility in responding to customer needs, customer service, product diversification, and the frequent introduction of new or improved products. This rating was based on a five-point scale where a score of 1 indicates low

Table 5B: Areas of Intense Competition by Industry

Areas of competition	Bakery	Cereal	Dairy	Fish	Fruit and vegetables	Meat	Other	All
	percentage of establishments reporting a score of 4 or 5							
Customization of products	50	60	63	35	62	45	60	52
Price	74	83	88	85	90	77	82	82
Flexibility in responding to customers' needs	70	75	71	58	72	62	60	66
Quality of products	75	77	81	78	84	68	69	75
Customer service	75	72	79	70	80	71	68	73
Offering a wide range of related products	58	51	66	40	72	51	58	55
Frequently introducing new or improved products	47	43	50	21	42	39	46	41

intensity, 3 medium intensity, and 5, high intensity. Once again, the percentage of establishments that gave a score of 4 or 5 in each area are reported (Table 5B).

For most establishments, price competition is the most intense form of competition. This is followed by product quality, then customer service. This holds across all industries. Only for cereal is flexibility in responding to customer needs as important as product quality and customer service.

Customization of products and the frequent introduction of new products are the areas of least importance. Even so, they are considered to be areas of moderate to high competition by between roughly 40% and 60% of establishments across all industries except fish. Managers in the dairy industry as well as in the fruit and vegetable industry generally give above average ratings in all areas of competition. Managers in the meat and fish industries give below average ratings.

5.3 *Differences by Size of Plant and Country of Control*

Differences between the competitive environment faced by smaller and larger plants can arise if the two groups serve different market segments.[9] A comparison of the sources of uncertainty outlined by the two groups (Appendix Table A5.1) indicates that plants of different sizes give about the same ranking to the different sources of market uncertainty identified in this study. Likewise, plants of all size groups give the same ranking to the most important areas of competition in their industry (Appendix Table A5.2).

Despite these broad similarities in the *rankings,* there are differences in the absolute value that is attached both to the degree of competition and the nature of the strategic response of different firms. Managers in the largest size group are more likely to give a higher rating to the threat of imports, new competitors and substitution of suppliers. Larger plants are also more likely to indicate that their market segment gives greater emphasis to innovative strategies that involve new products, customization, and a wide range of product offerings than small firms. In keeping with scale advantages of larger firms, they are more likely to stress that price is used as a competitive strategy in their market segment. This indicates that large and small firms do not operate in the same market segments.

Managers of Canadian- and foreign-controlled plants do not differ greatly in their ratings of sources of uncertainty. Foreign-controlled plants are a little more likely to be concerned about most specific areas of competition but the only appreciable difference is a higher rating for the importance of customization of products (Tables A5.1 and A5.2).

5.4 *Summary and Conclusions*

Table 5C provides a summary of our findings about the competitive environment—the uncertainty faced and the intensity of product market competition. The uncertainties that firms face are ranked in descending order of importance in the first column, and the areas of product market competition are ranked the same way in the second column.

[9] See Caves and Porter (1977) and Newman (1978) for studies that investigate differences across size groups.

Table 5C: Uncertainty and Nature of Competitive Environment

Rank	Uncertainty of Environment	Areas of Product Market Competition
1	Threat of new competitors	Price
2	Supplier substitution	Product quality
3	Threat of suppliers or customers becoming competitors	Customer service
4	Consumer demand difficult to predict	Customer needs flexibility
5	Competitors' actions difficult to predict	Diversity of products
6	Imports offer competition	Customization of products
7	Rapidly changing production technology	Frequent introduction of new products
8	Product obsolescence	

The threat of new competitors, supplier substitution, and concerns about suppliers or customers becoming competitors are generally regarded as the three areas of greatest uncertainty. Responding to this pressure, firms give their greatest attention to price, quality and service as competitive strategies.

The unpredictability of competitors and consumer demand is of secondary importance. Corresponding to this on the product strategy side is the importance attached to the diversity and customization of products.

Product obsolescence is seen as relatively unimportant; consistent with this is the lower emphasis given by food-processing firms to the frequent introduction of new products.

Finally, it is noteworthy that rapidly changing production technology is one of the least important sources of uncertainty for all but the dairy industry. Only about one-third of food processors consider rapid changes in technology to be a major feature of their competitive environment. Technological obsolescence then will not be the driving force behind the adoption of new technologies. Rather, new technologies are likely to be used primarily to retain existing customers through price and quality competition. The exception is the dairy industry where half of all managers rate changing technology as a major source of uncertainty.

Broad differences in the competitive environment exist across sectors in the degree of competition that firms perceive to exist in their industry. Most of these differences are related to the threat posed by imports. In addition, there are significant intra-industry differences in the degree of uncertainty and the type of competitive strategies that are adopted. Managers of large plants are more likely to be concerned with the threat of new sources of supply and to give relatively more attention to innovative product strategies. There are, however, surprisingly few differences between Canadian- and foreign-controlled plants in their views of the competitive environment.

Appendix Chapter 5

Table A5.1: Differences in Sources of Uncertainty by Size Group and Country of Control

Sources of uncertainty	Employment Size Group					Nationality	
	10 - 19	20 - 49	50 - 99	100 - 249	250+	Canada	Foreign
	percentage of establishments reporting a score of 4 or 5						
Imports offer substantial competition	32	39	37	42	48	38	44
Consumer demand is difficult to predict	34	42	42	41	39	40	41
Competitors' actions are difficult to predict	36	39	44	35	44	38	45
The arrival of new competitors is a constant threat	43	52	53	53	61	52	47
Products quickly become obsolete	14	12	19	22	16	17	13
Production technology changes rapidly	28	36	36	37	43	35	34
Competitors can easily substitute among suppliers	45	46	53	53	61	50	52
Customers and/or suppliers can become competitors	47	42	51	50	47	47	50

Table A5.2: Differences in Areas of Competition by Size Group and Country of Control

Areas of competition	Employment Size Group					Nationality	
	10 - 19	20 - 49	50 - 99	100 - 249	250+	Canada	Foreign
	percentage of establishments reporting a score of 4 or 5						
Customization of products	45	50	58	56	60	50	69
Price	76	76	84	88	94	81	88
Flexibility in responding to customers needs	59	67	70	66	72	65	72
Quality of products	68	78	75	75	80	74	79
Customer service	67	76	74	70	78	72	77
Offering a wide range of related products	54	51	57	54	67	54	61
Frequently introducing new or improved products	40	35	46	40	48	40	47

Chapter 6 – Business Strategies

6.1 General Strategies

Firms in the food-processing sector tend to choose competitive strategies that focus primarily on price, quality and service as ways to deal with uncertainties in their environment. Their competitive stance is supported by competencies developed through both general and specific business strategies in the key areas of marketing, production, management, human resources and technology.

This section examines the type of specific competencies that firms develop in order to deal with their competitive environment. Since this study focuses on the use of technology, we will concentrate here on the technology strategies that firms emphasize. However, we expect the adoption of advanced technologies and technology-related business practices to be related to the other business strategies pursued by firms.

A "business strategy" is a means or plan used by firms to achieve their basic goals, such as increasing profits and growth. Strategies can be defined in terms of high-level objectives or in terms of more immediate activities—that is, *what* firms do and *how* they do it. For example, a firm may wish to upgrade the skills of its labour force, which can be accomplished by hiring new workers or by implementing training programs. Alternately, a firm may wish to improve the quality of its product. This objective can be attained by implementing a total quality management program (a practice), developing high-quality suppliers, establishing new processing systems that improve quality, or using new quality-related technologies in the areas of process testing.[10]

The business strategies examined in this study cover a range of general and specific strategies in the following five functional areas: marketing, production, management, human resources, and most importantly, technology. Using a scale in which 1 represents low importance, and 5 represents high importance, plant managers were asked to indicate the importance they place on 23 factors in the five areas.

The strategies we examine are identified in Table 6A, along with the measure of importance that is attached to them by food-industry managers. This measure is the percentage of managers that gave a score of 4 or 5 (moderate to high importance) to each of the factors listed.

6.1.1 Marketing strategies

Marketing strategies are high-level strategies that drive a firm's operations and are designed to increase demand for its output. They are related to the way a firm views its competitive environment. Such strategies may focus on existing markets or products or on new markets or products. Focusing on existing markets or products requires companies to focus on core strength. Strategies that focus on new markets tend to be more aggressive and more innovative.

In order to evaluate the extent to which firms in the food-processing industry emphasize core business as opposed to new business, managers were asked to rank (again on a scale of 1 to 5) the importance they attribute to a strategy that focuses on existing products in present markets versus strategies involving new products and the penetration of new markets.

The strategy considered the most important by food-processing firms was that of maintaining existing products in current markets, which is consistent with their need to confront the intense product competition that exists in the food-processing sector. The largest percentage of establishments (89%) emphasized the importance of this strategy, compared with some 58% that stressed the need to introduce new products in current markets or current products in new markets. Only 40% gave a high rating to the strategy of introducing new products in new markets.

Despite the overwhelming emphasis given to existing markets, new-product development is very important for some 60% of establishments.[11] Since new products often require new technologies and new processes, we would anticipate considerable demand for new technologies in the food sector.

[10] The role and characteristics of business strategies are discussed in books and articles such as Newton (1996); Noori (1990); Flood (1993); Juran (1988); and Kane (1996).

[11] For example, fat and sugar substitutes have led to major "diet" or "light" product categories.

Table 6A: Importance of Business Strategies

Business Strategies	Bakery	Cereal	Dairy	Fish	Fruit and vegetables	Meat	Other	All
	percentage of establishments reporting a score of 4 or 5							
Markets and Products								
Current products in present markets	79	91	94	90	89	89	95	89
New products in present markets	60	57	54	51	50	53	73	58
Current products in new markets	51	51	58	66	69	57	60	58
New products in new markets	36	37	34	46	39	38	43	40
Technology								
Using other's technology	29	49	55	37	49	47	42	43
Improving own technologies	57	66	73	63	71	66	73	67
Creating new technologies	43	41	33	48	36	38	42	41
Accessing R&D facilities	23	22	33	26	26	26	36	27
Production								
Using new materials	25	47	27	37	38	33	41	36
Using existing materials more efficiently	68	77	72	73	71	76	77	74
Increasing line speed	62	69	64	73	74	72	71	69
Cutting labour costs	73	67	74	74	67	74	71	72
Implementing computer controlled processes	32	56	59	32	46	36	51	44
Using high quality suppliers	65	80	81	70	77	71	78	74
Reducing energy costs	52	69	65	64	64	66	55	62
Reducing waste disposal costs	51	52	65	50	60	61	58	56
Management Practices								
Continuously improving quality	80	90	92	88	85	85	92	87
Strategic alliances	30	33	43	25	31	32	38	33
Innovative organizational structure	28	32	32	27	28	32	43	32
Using information technology	40	48	52	46	46	49	47	47
Human Resources								
Continuously training staff	56	70	65	58	54	64	64	62
Innovative compensation packages	18	21	28	22	25	29	25	24
Recruiting skilled employees	44	49	62	37	41	49	45	46

At the industry level, the emphasis on new product development is relatively similar across industries—with "other" industries leading the way. Establishments in the bakery, cereal, and "other" industries place more emphasis on developing new products than on selling in new markets, while establishments in the fruit and vegetable, and fish product industries emphasize new markets over new products. Dairy and meat establishments stress both equally.

6.1.2 Production strategies

Production strategies also affect the need for new technologies. A technology strategy focuses on the implementation of new machines and processes. Accompanying this are broader production issues—such as how much emphasis to place on improving the efficiency of existing inputs, whether to stress new materials, whether to use high-quality suppliers, how to implement reductions in labour costs, or the extent to which the engineering department should focus on increasing line speed.

Of the eight strategies identified in the survey, four (using high-quality suppliers, using existing materials more efficiently, cutting labour costs and increasing line speed) were rated as very important by about 70% or more of the plants. Using high-quality suppliers could be related to either quality or cost considerations, while the other three are more closely associated with cost considerations. In addition, strategies to reduce the cost of energy and waste disposal were highly rated by most managers. These results indicate that cost reduction is a high priority in the food industry. The emphasis that is placed by food-processing establishments on the various cost-reduction production strategies is consistent with their concern about new competition and competitors and their emphasis on price competition. These firms worry about the efficient use of inputs—both materials and labour—as well as about having good supplier contacts.

There is little or no difference in the emphasis attributed to the list of production strategies across industries. Each of the food-processing industries gives about the same importance to cutting costs, both with respect to material use and labour, and to decreasing capital costs by increasing line speed.

6.1.3 Management strategies

Management strategies are concerned with all aspects of a plant's operations. Managers oversee production techniques, human resource strategies, technology strategies and financial requirements. All these help to define the culture of the organization. As such, management strategies are both numerous and diffuse.

Our survey focused on specific strategies in four areas that are perceived to be related to innovation and technology use: quality as a product strategy; the use of information technology that complements and facilitates advanced technologies on the plant floor; and two aspects of organizational change—the use of new organizational structures (such as cross-functional teams), and the use of strategic alliances.

The emphasis given to quality improvement stands out above the other management practices. Eighty-seven percent of all plants rate as very important the broad strategy of continuously improving quality, a percentage that is equalled only by the importance given to maintaining current products in present markets. This is consistent with the high degree of importance placed on product quality competition within the food-processing industry

The other three management strategies are relatively specific and contribute to both productivity and quality improvement. The use of information technology ranks second behind quality improvement; it was rated highly by 47% of managers. Fewer managers considered entering into strategic alliances or joint ventures, or introducing innovative organizational structures, to be very important.

The patterns across most of the industries are broadly the same as the average of the entire sector; the exception is that the dairy and "other" industries are consistently above the average, while the bakery industry is consistently below the average.

6.1.4 Human resource strategies

The adoption of new technologies often affects the type of employee skills required as well as the number of employees. Baldwin, Sabourin and Rafiquzzaman (1996) found skill shortages to be one of the most important impediments to the adoption of advanced manufacturing technologies. Baldwin, Gray and Johnson (1995) reported that firms that had introduced new advanced technologies in the manufacturing sector were more likely to have implemented a training program.

The extent to which firms in the food-processing sector emphasize the development of their workers can be gauged by the importance managers give to three strategies: the continuous training of staff, the introduction of innovative compensation packages and the acquisition of skilled employees. Of the human resource strategies cited, managers consider training to be the most important, followed by the recruitment of skilled employees. The strategy of continuously training staff is rated as very important by two-thirds of the plants, while 46% rate the recruitment of skilled employees as very important.

Few consider offering innovative compensation packages, such as equity shares, to be important. Such packages (stock options, for example) are used as a way to give current employees added incentives or to attract new employees.

The emphasis on training over recruitment partially reflects a general view of technological change as a progressive, adaptive process—one in which firms must develop firm-specific skills to go with the gradual improvement of their technological capabilities.

The general pattern that emphasizes training over other strategies is found across all industries. Only the dairy industry considers recruiting skilled personnel to be as important as training.

6.1.5 Technology strategies

A technology strategy is an integral part of the overall business strategy of establishments in the food-processing sector. Technology is directly related to the kinds of products produced and how they are produced. It also influences human resource requirements. As with the other strategic areas, technology strategies range from the general to the specific.

At the most general level, a firm's technology strategy might focus on making incremental improvements by modifying its own technologies or on adopting brand new technologies. The latter can be accomplished by buying the technology from others (for example, by purchasing equipment and plans), or by creating new technology. If the choice is to create new technologies, then they may be developed by a firm's research and development (R&D) department, or elsewhere in the firm.

The decision to emphasize the upgrading of production technology rather than make a radical replacement tends to be based on such considerations as cost, risk and the need to integrate new improvements with current machinery and equipment.

In general, the largest group of firms focuses on making incremental improvements; two-thirds consider it important to improve their existing technology.[12] Despite this emphasis on incrementalism, a good proportion of firms focus their attention on brand new technologies. Some 41% emphasize the creation of new technology by themselves; some 43% emphasize the purchase of technology from others (Table 6A). Industries are similar to one another in the emphasis on incremental improvements. As for the other technology strategies, the dairy, fruit and vegetable, meat and cereal industries tend to place relatively more emphasis on buying technologies from others than on creating new technologies themselves. The fish and bakery industries are the reverse, while the "other" industry ranks them equally important.

The strategy involving R&D is considered the least important by firms; only about 27% accord importance to this option. The fact that this proportion is lower than for other new technologies is not surprising. There is evidence to indicate that R&D, although important to the innovation process, is not essential. Recent studies (Mowery and Rosenberg 1989; Baldwin, Hanel and Sabourin 1999) have shown that production and engineering departments are also important contributors to innovation. Although important, R&D is neither a necessary nor a sufficient condition for innovation (Åkerblom et al.1996; Baldwin 1997).

6.1.6 Relationship of business strategies to size of establishment and country of control

As was the case with the economic environment, there is little difference among plant-size groups in the order of importance given to the several business strategies (see Appendix Table A6.1).

However, larger firms are more likely to place more absolute stress on the importance of several of the technology strategies—improving their own technology, and using the technology of others. They are also more likely to use information technology in management.

In accordance with their greater emphasis on price as a corporate strategy, larger firms also give greater stress to lowering production costs by saving on labour—although here the differences exist primarily between the largest three classes and the smallest two classes. They also put relatively greater emphasis on using quality suppliers than do the smaller plants.

Larger plants are more likely to be using strategic alliances and emphasizing changes in organizational structure. They are more likely to focus attention on human resource strategies such as recruiting skilled labour and on upgrading the skills of their labour force with training programs.

The rankings of business strategies by Canadian- and foreign-controlled plants are also much the same (see Appendix Table A6.1). In several cases, including the use of other firms or organizations to develop new technologies, improving current technologies, using information technologies and computer processes, foreign-controlled plants put more emphasis on a strategy. To some degree these results would be related to their larger plant size.

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[12] Even when technology is purchased from others, it often needs to be adapted to the needs of the purchaser.

Table 6B: Importance of Technological Strategies by Industry

Technological strategies	Bakery	Cereal	Dairy	Fish	Fruit and vegetables	Meat	Other	All
	percentage of establishments reporting a score of 4 or 5							
Skilled personnel	46	66	65	51	55	61	62	58
Use of advanced technologies	27	39	54	28	47	46	41	40
Research and development	22	43	34	25	48	39	45	36
Product innovation	47	53	54	31	56	50	62	51

6.2 *Specific Innovation and Technology Strategies*

Focusing on the broad, general strategies employed by firms in the food-processing industry allows us to rank the importance placed on technology, marketing, production, management and human resource strategies. For example, we can ascertain whether core marketing is considered more important than innovative marketing, whether incremental or more radical technological change is emphasized, whether there is a focus on cost-cutting production strategies, and finally, if and how it is considered important to develop a skilled labour force.

The advantage of using broad questions in the survey is that they allow us to place these issues in a general context. The disadvantage is that the large number of options offered respondents (plant managers) might have made it difficult for them to directly compare the relative importance of each.

Nevertheless, using these broad questions, we can tentatively rank the importance placed on the most innovative strategies. The greatest emphasis is placed on human capital and innovation. Some 62% of firms stressed training, followed by about 58% that stressed new products. About 41% indicated that they concentrated on creating new technologies. The smallest group of managers (27%) said that a focus on R&D was important.

This ranking is confirmed by the answers to a more focused question that asked managers to evaluate the relative importance of only four key aspects of an innovation strategy: the use of advanced technologies; product innovation; the use of skilled personnel; and the development of a research and development capability. Plant managers rated the significance of each of these to their firm on a five-point scale, ranging from 1 for low importance to 5 for high importance. As do other tables, Table 6B reports the percentage of establishments that scored a 4 or 5 for each of these areas.

These answers confirm the relative rankings presented above. The use of skilled personnel ranks highest, with 58% of food-processing plants indicating it to be important. This is followed by product innovation at 51%. The use of advanced technologies and research and development are less important.

There is some variation among industries with respect to the importance placed on these broad technology strategies. According to the first question, for example, the use of technologies developed by others is considered to be very important by 55% of plants in the dairy industry, but only 29% in the bakery industry (Table 6A). Similarly, results of the second question show that about 50% of plants in the dairy and fruit and vegetable industries rank the use of advanced technologies highly, while less than 30% of plants in the bakery and fish industries do so (Table 6B).

At 62%, the "other" industry places the greatest emphasis on product innovation—double the rate of the fish industry. As for R&D, the fruit and vegetable, as well as the "other" industries rate it highest. The dairy and cereal industries lead the others in the emphasis placed on skilled personnel as part of a technology strategy.

For the dairy industry, the use of advanced technology and product innovation are equal in importance—not far behind skilled personnel. It is also the case that the dairy industry perceives rapidly changing production technology to be a more severe problem than do other industries. As we will discuss later on, this is in keeping with the importance attributed to the use of advanced technologies—process technologies in particular (Table 6B).

The fish industry leads the others in the emphasis it places on creating new technologies. Establishments in the bakery and fish products industries are unique in the relative emphasis that they give to creating new technologies as opposed to acquiring them from others. This could mean that fewer off-the-shelf

advanced technologies suitable to these industries are available from commercial sources and that those used tend to be proprietary. The "other" industry gives these methods equal weight while the rest prefer to purchase new technologies from others (Table 6A).

6.2.1 Relationship of specific innovation and technology strategies to plant size and country of control

Given their greater emphasis on business strategies involving technologies, we would expect that larger plants would also be more likely to stress each of the more specific technology strategies. This is the case, although the difference is primarily between the largest, the three middle sized classes, and smallest size groups (see Appendix Table A6.2). Large plants once more also give considerably greater emphasis to the enhancement of labour skills.

Also consistent with differences reported previously with respect to business strategies, foreign-controlled plants give more weight to each of the specific technology strategies than do Canadiancontrolled plants (Table A6.2).

6.3 Summary and Conclusions

This section has placed the technology strategies of food-processing firms in the context of the emphasis they place on a range of marketing, production, management and human resource strategies. The challenge of intense price and quality competition in the food-processing sector leads firms to focus not only on satisfying existing customers but also on developing new products as part of their marketing and product strategies. Production strategies support these marketing strategies by placing emphasis on increasing productivity or reducing costs. This is accomplished by using materials more efficiently, cutting labour costs and increasing line speed. Management strategies tend to stress continuous quality improvement and human resource strategies emphasize the continuous training of staff.

Technology and innovation strategies support these marketing, production, human resource and management strategies. The most important general strategy for improving technological competence is the incremental improvement of current technologies. When it comes to implementing new technologies, plants are just about as likely to obtain them from others as to create them themselves. A significant number of the latter group believe that it is important to have their own R&D, although other departments are also likely to be involved in creating new products and processes. About 40% of plants believe that the use of advanced technology is very important, and 50% emphasize product innovation as part of their technology or innovation strategy.

There are significant differences in the environment and in the technology strategy pursued by large and small firms. Large firms perceive that imports and new competitors offer a greater threat. They place a greater emphasis on price as a competitive strategy. They place a greater emphasis on improving their own technology and acquiring new technologies from others. They worry more about upgrading the skill of their labour force. All of this substantiates the view that larger firms operate in different market segments than do small firms and use quite different strategies. In keeping with the view that larger firms are more likely to operate in more mature stages of the product life cycle or in markets where economies of scale are more important, they focus more on price and they are more likely to use an advanced technology strategy to support their overall strategic thrust.

There are notable differences among industries in the emphasis placed on some of these business strategies. For example, the bakery, cereal and "other" industries put more emphasis on new products in their marketing strategies. The dairy industry is unique in the emphasis it places on hiring skilled employees, perhaps reflecting the rapid changes in technology in this industry. The dairy, fruit and vegetable and meat industries lead the others in the importance that managers attach to the use of advanced technology, while the "other" industry accords more emphasis to having a product innovation strategy.

Although plants of differing sizes and nationalities do not differ in terms of the ranking of the relative importance of business and technology strategies, large plants and foreign-controlled plants are more likely than others to stress both the more general and more specific technology strategies. These high-level and more specific business strategies influence the business practices of firms and hence their rates of innovation and use of advanced technologies.

Appendix – Chapter 6

Table A6.1: Differences in Business Strategies by Size Group and Country of Control

Business strategies	Employment Size Group					Nationality	
	10 - 19	20 - 49	50 - 99	100 - 249	250+	Canada	Foreign
	percentage of establishments reporting a score of 4 or 5						
Markets and Products							
Current products in present markets	89	89	88	90	93	89	92
New products in present markets	53	52	59	69	65	57	70
Current products in new markets	49	55	63	65	65	58	57
New products in new markets	35	33	47	45	43	39	44
Technology							
Using other's technology	40	34	35	56	66	41	58
Improving own technologies	52	66	70	71	84	65	78
Creating new technologies	35	37	51	42	44	41	43
Accessing R&D facilities	21	27	30	30	35	27	29
Production							
Using new materials	35	27	42	41	37	34	47
Using existing materials more efficiently	70	69	78	80	79	73	85
Increasing line speed	57	69	81	73	68	68	78
Cutting labour costs	61	69	80	75	82	72	74
Implementing computer controlled processes	34	39	44	50	63	42	58
Using high quality suppliers	71	71	72	77	86	73	87
Reducing energy costs	63	57	66	63	60	61	70
Reducing waste disposal costs	49	53	60	60	66	55	61
Management Practices							
Continuously improving quality	86	84	89	91	91	87	95
Strategic alliances	23	30	37	38	44	32	36
Innovative organizational structure	22	29	37	39	47	31	45
Using information technology	34	39	48	58	71	45	59
Human Resources							
Continuously training staff	55	61	62	65	76	60	77
Innovative compensation packages	19	25	23	25	34	24	23
Recruiting skilled employees	41	42	43	54	62	45	58

Table A6.2: Differences in Key Strategies by Size Group and Country of Control

Technological strategies	Employment Size Group					Nationality	
	10 - 19	20 - 49	50 - 99	100 - 249	250+	Canada	Foreign
	percentage of establishments reporting a score of 4 or 5						
Skilled personnel	52	55	54	62	78	57	67
Use of advanced technologies	30	36	41	45	57	38	48
Research and development	27	38	36	40	45	35	46
Product innovation	42	52	50	52	64	49	60

Chapter 7 – Innovation

Innovative activity is a key determinant of the technology strategy pursued by firms. Firms that introduce new products and new processes will have a greater need for the new advanced technologies, which are the focus of this study.

The innovative activity of firms grows out of their strategies and practices and directly affects technology use. In our previous discussion of broad general strategies, we noted that the emphasis placed on product innovation is greater than that placed on advanced technologies, but that neither was the most important business strategy. This does not mean innovation does not occur in the food-processing sector, just that core markets are given the greatest emphasis. In order to provide an overview of the importance of innovation, this chapter investigates the intensity of activity in both these areas.

Plant managers were asked to report the number of major new innovations that had been introduced into their plant in the past three years. A three-way classification was used: product-only innovations (those not requiring process innovation); combined product–process innovations (product innovations requiring process innovation); and process-only innovations (those not associated with product innovation). Product innovation is the commercial adoption of a substantially new or improved good or service. Process innovation is the adoption of significantly improved production methods and may involve changes in new technologies, production procedures and/or distribution systems. Process innovations may produce new or improved products or increase the efficiency of the production and delivery of existing products.

In the three years preceding the survey, 72% of the plants in the industry had introduced at least one major product or process innovation. Food-industry plants were somewhat more likely to have introduced at least one product innovation (69%) than a process innovation (60%)—though the differences are not large. There was, of course, considerable overlap; about half the plants adopted at least one major product innovation that did not require a process innovation, and about half adopted a product innovation that did require a process innovation. A smaller but substantial number (36%) introduced a major process technology not associated with a major product innovation (Table 7A).

The "other" industry, which gave the greatest emphasis to a new-product marketing strategy and improving technology, is the most likely to have introduced each type of innovation. In most cases, it is followed by the fruit and vegetable, and dairy industries. The bakery industry is one of the leaders in introducing product innovations; while it is one of the least likely (along with the cereal industry) to have introduced any process innovation.

As would be expected, many plants introduced more than one major innovation during this period. For example, 31% introduced seven or more product innovations and 19% introduced seven or more process innovations (Table 7B).

Innovative activity is positively associated with size of plant, particularly process innovations. Plants with 250 or more employees were three times more likely than those with 10 to 19 employees to have made a process innovation not associated with a new product, and almost twice as likely to have made a process innovation that was associated with a product innovation. The fact that the size differentials are greater for process than product innovations supports the hypothesis of Cohen and Klepper (1996) that size should matter more where information asymmetries make it difficult to realize the results of innovative activities by selling the innovation to others. A firm faces greater difficulty in realizing the return to a process innovation in any way except through own-firm production since information asymmetries make it more difficult to license a process than a product.

In all of these categories of innovation, foreign-controlled plants are more likely than Canadian-controlled ones to have introduced at least one innovation. The differences are greater for process innovations than for product innovations, which partially reflects size differences. These relationships between the incidence of innovation and size and nationality of control are consistent with the relationships between technology use and plant size and control observed below.

Table 7A: Incidence of Product and Process Innovation in the Last Three Years

Establishment characteristics	Type of Innovation					
	Product Only	Combined Product-Process	Process Only	Any Product Innovation	Any Process Innovation	Any Innovation
	(a)	(b)	(c)	(a or b)	(b or c)	(a, b or c)
	percentage of establishments					
Food Industry	51	53	36	69	60	72
Sub-Industry						
Bakery	58	51	20	75	52	75
Cereal	44	39	38	59	54	65
Dairy	58	58	40	74	63	78
Fish	32	51	26	61	59	65
Fruit and vegetables	56	54	41	76	60	77
Meat	47	50	39	61	58	66
Other	64	66	50	81	73	83
Size (employees)						
10 – 19	39	39	21	56	43	58
20 – 49	52	50	30	72	57	74
50 – 99	53	53	42	71	64	77
100 – 249	56	62	44	74	70	78
250+	60	74	60	81	81	84
Control						
Canada	50	52	34	68	58	71
Foreign	59	62	55	75	75	80

Table 7B: Number of Product and Process Innovations Introduced in the Last Three Years

Type of innovation	Number of Innovations						
	None	1	2 - 3	4 - 6	7 - 12	13 +	At Least 1
	percentage of establishments						
(a) Product-only innovation	49	7	14	12	7	10	51
(b) Combined product-process innovation	47	12	20	10	7	3	53
(c) Process-only innovation	64	8	14	7	4	2	36
(d) Any product innovation (a or b)	31	7	17	14	15	16	69
(e) Any process innovations (b or c)	40	7	20	15	11	8	60
(f) Any innovation (product or process) (a, b or c)	28	6	17	13	18	19	72

In summary, the majority of firms in the food-processing industry are innovative. Over the 1995 to 1997 period, almost 72% of plants introduced a product or process innovation or a combination of the two. Despite the *relatively* lower emphasis given by food-processing firms to new product introduction, either as a product strategy or as a marketing strategy (compared with maintaining market share in current markets), 69% of plants saw the introduction of a new product. Moreover, while relatively low emphasis is given to the strategy of introducing advanced technologies compared with product innovation, plants in the food-processing industry are actually introducing process innovations at a rate that is only slightly behind the rate at which they introduce product innovations—since so many product innovations simultaneously involve process innovations. This focus on innovation, particularly process innovation, is inextricably tied to the use of advanced technologies.

Chapter 8 – Business Practices

The business strategies that firms adopt are implemented through specific practices. For example, a firm's decision to emphasize quality may be carried out through a range of relevant activities—from the certification of suppliers to the implementation of total quality management systems. A product innovation strategy may be implemented with rapid prototyping or concurrent engineering. A production strategy to reduce the cost of materials or distribution might focus on activities ranging from materials requirement planning to just-in-time inventory control. In this chapter, we examine the emphasis given to practices that enhance quality, facilitate materials and distribution management, and contribute to product and process development. The connection between these practices and the use of technology will be further developed in subsequent chapters of the report.

The business practices that are investigated here serve a firm's broad goals in a direct manner. Getting them right can make a difference to a firm's long-run success. Gordon and Wiseman (1995) found that the plants that were most successful in meeting their operational goals were those that followed through on their strategic priorities by adopting appropriate business practices. Other research confirms the critical nature of business practices in the food-processing sector.[13] Jayanthi et al. (1996) estimated the effect of structural variables such as plant size, and of infrastructural variables such as business practices, on plant efficiency scores for a sample of food-processing plants in the United States. They found that infrastructural variables had an influence on efficiency.

What are the most appropriate practices for a technologically advanced plant? Can we isolate a small set of practices that are essential, or are there numerous prerequisites to success? In a related context, Baldwin and Johnson (1995) found that innovative small and medium-sized establishments place more emphasis on a broad range of competencies—from management, human resources, marketing, financing, government programs and services, to production efficiencies. We might, therefore, expect technologically innovative food-processing plants to also emphasize a broad range of practices in each of the areas examined here.

This chapter examines the extent to which selected business practices are being pursued by food-processing firms, and investigates the way in which general strategies, such as product management, are reflected in the business practices that are implemented. The information presented here will set the scene for the description of technology use that follows. Some business practices are associated with the use of specific technologies or with the goals that specific technologies can be expected to meet. Outlining the importance firms give to key business practices allows us to better understand the forces behind technology use.

This study covered 24 business practices, which were divided into three groups: product quality; materials and distribution management; and product and process development. Seven to nine practices were identified in each group.[14]

All food-industry plants use at least one of these practices; many use more than one. Some 86% used four or more. These activities are relatively widespread. In keeping with the primary emphasis given to quality, the percentage of firms that have adopted at least one business practice, or four or more, is highest for product quality. Materials and distribution management is second, and product and process development third. Fifty-seven percent used at least one practice from each of the three categories. The following sections discuss the use of these practices by category.

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[13] Management practices related to the development, acquisition and use of technology are examined in some detail by Noori (1990). The use of a number of technological and human resource practices in U.S. agribusiness firms was examined by Chacko et al. (1997).

[14] The use of these and other practices are discussed in books and articles such as those by Fallon (1983); Flood (1993); Juran (1988); Kane (1996); Kennedy (1991); Noori (1990); Noori and Radford (1990); and *The Financial Times* (1995). Information on the Internet or World Wide Web also is available from the International Standards Organization, Guelph Technology Centre and the Food Institute of Canada's foodnet.

Table 8A: Adoption of Advanced Business Practices by Industry

Business practices	Bakery	Cereal	Dairy	Fish	Fruit and Vegetables	Meat	Other	All
	percentage of establishments							
Any Business Practice								
At least 1	91	97	98	96	97	92	99	100
4 or more	80	87	95	87	94	78	91	86
Product Quality								
At least 1	90	96	98	95	97	89	97	94
4 or more	62	75	86	77	82	68	76	74
Materials and Distribution Management								
At least 1	68	80	74	61	82	66	81	72
4 or more	25	37	44	21	39	28	38	32
Product and Process Development								
At least 1	62	61	71	65	78	62	74	67
4 or more	22	23	27	23	41	23	38	28
At least 1 practice from each group	52	56	61	48	72	49	65	57

8.1 Use by Industry

8.1.1 Product quality and safety

We identified eight practices in the category of product quality and safety. Although all eight contribute to both quality and safety, five are primarily quality-oriented and three are more safety-oriented. Quality here refers to product characteristics such as taste, nutrition, appearance and convenience. While food quality also includes food safety, safety considerations (such as bacterial levels and chemical contamination) are sufficiently distinct and important that it is useful to consider them separately. For the food industry as a whole, 94% of plants use at least one of the eight practices in this category, and 74% use four or more (Table 8A).

The quality-oriented practices included continuous quality improvement, acceptance sampling, certification of suppliers and plant-quality certification. Quality improvement, benchmarking and plant-quality certification are procedures for improving performance in all areas. Benchmarking includes comparing a plant's standards in a wide range of areas to an ideal standard or to an industry leader. Plant-quality certification involves third-party standards (which are industry specific) and verification. Examples are the programs of the International Standards Organization (ISO) and the American Baking Institute. For continuous quality improvement and benchmarking, the specific approach followed—goals, criteria applied, and assessment of progress—are internal management decisions. As their names imply, acceptance sampling and the certification of suppliers focus on product quality (and cost) as related to the quality of inputs.

Continuous quality improvement (CQI) and acceptance sampling are used by three-quarters of all plants, the second highest rate of all the business practices identified in this study. Benchmarking is used by only half of food processing plants. Just 23% of plants were qualified under ISO or another broad, plant-level quality certification program (Table 8B).

Food safety is fundamental and is subject to government regulations that apply to products, plant, equipment and processes. An alternative to the regular inspection program is provided to plants qualifying under the Canadian Food Inspection Agency's Food Safety Enhancement Program (FSEP).

FSEP includes the adoption of "prerequisite programs" (which involve meeting a number of plant-based hygienic conditions) and the adoption of the more product-specific Hazard Analysis Critical Control Points (HACCP) program. The use of HACCP is also a requirement imposed by some buyers on their suppliers. Half the plants reported using the FSEP and 64% said they used the HACCP program. This would indicate that HACCP is used for more than just qualifying for FSEP.

Good manufacturing practices (GMP) include international standards for food hygiene that apply to buildings, equipment and practices. The prerequisite program requirements of FSEP are consistent with GMP. Again, some buyers require suppliers to meet these standards. In fact, 81% of plants reported the

Table 8B: Use of Product Quality Practices by Industry

Practice	Bakery	Cereal	Dairy	Fish	Fruit and Vegetables	Meat	Other	All
	percentage of establishments							
Continuous quality improvement (CQI)	74	77	77	75	81	77	80	77
Benchmarking	41	55	60	36	57	37	55	47
Acceptance sampling	68	87	80	75	82	68	80	76
Certification of suppliers	44	52	70	59	65	53	65	57
Good manufacturing practices (GMP)	79	80	92	74	87	76	86	81
Hazard analysis critical control points (HACCP)	34	53	85	87	74	65	63	64
Food safety enhancement program (FSEP)	50	22	75	46	55	60	51	50
Plant quality certification	23	19	23	31	33	14	22	23
Other	3	2	1	14	8	8	10	7

use of GMP, making it the most commonly used of all the business practices.

For the most part, the percentage of plants using at least one, or at least four, of these quality and safety practices (and the other types of business practices as well) did not differ greatly across industries (Table 8A). With respect to the frequency of adoption of individual practices, the "other," fruit and vegetable, and dairy industries tended to be the leaders, while the bakery and meat industries tended to be below average. The largest differences in individual adoption rates were in the use of FSEP and HACCP. For example, 85% of dairy plants use HACCP compared with 34% of firms in the bakery industry (Table 8B).

8.1.2 Materials and distribution management

Materials and distribution management practices facilitate cost reduction and improved timeliness of delivery. The seven practices included in this category are materials requirement planning (MRP), manufacturing resource planning (MRPII), process change-over time reduction, just-in-time inventory control, electronic work order management, electronic data interchange and distribution resource planning. They all involve the automation and integration of materials handling and distribution functions. As such, they use advanced computer-based systems.

Seventy-two percent of plants use at least one of the seven practices listed in the questionnaire, and 32% use four or more (Table 8A). These rates are below those of the quality-related practices.

Adoption rates for individual practices also tended to be lower in this category than in the product quality category. The most commonly used practices, at about 50%, were just-in-time inventory control and materials requirement planning. Electronic work order management and distribution resource management were the least used at about 20% each (Table 8C).

There are only minor differences in adoption rates among the individual industries. Exceptions include the low adoption rates for electronic work-order management and electronic data interchange in the fish industry. The "other," fruit and vegetable, and dairy industries are again among the leading industries in intensity and frequency of adoption.

8.1.3 Product and process development

The nine product and process development practices measured here are designed to increase the speed, efficiency and effectiveness of product and process development. Some of these practices are technology-based, such as computer-aided design (CAD), and process simulation. While the other practices may also use advanced technologies, they tend to be more procedure-oriented. For example, rapid prototyping and concurrent engineering focus on speeding up the development process and quality function deployment. Continuous improvement and process-value analysis focus on quality improvement. Process benchmarking is a means of identifying opportunities for improvement. Cross-functional design teams represent an organizational change designed to facilitate the overall development process.[15]

[15] Some of these practices (e.g., CAD) are used both for plant layout/design as well as for new products and processes.

Table 8C: Use of Materials and Distribution Management Practices by Industry

Practice	Bakery	Cereal	Dairy	Fish	Fruit and Vegetables	Meat	Other	All
	percentage of establishments							
Materials requirement planning (MRP)	43	59	52	45	47	44	52	49
Manufacturing resource planning (MRPII)	30	36	37	30	38	30	36	33
Process changeover time reduction	32	41	51	33	47	28	47	39
Just-in-time inventory control	52	53	56	39	64	49	55	52
Electronic work order management	15	34	21	7	24	16	28	20
Electronic data interchange	21	33	41	10	41	29	36	29
Distribution resource planning	17	27	30	13	23	20	22	21
Other	1	1	3	–	3	–	1	1

Table 8D: Use of Product and Process Development Practices by Industry

Practice	Bakery	Cereal	Dairy	Fish	Fruit and Vegetables	Meat	Other	All
	percentage of establishments							
Rapid prototyping	15	6	14	8	21	6	25	13
Quality function deployment	20	21	30	26	32	26	32	26
Cross-functional design teams	18	16	20	9	27	13	27	18
Concurrent engineering	13	10	16	12	23	13	24	16
Computer-aided design (CAD)	16	17	23	18	25	14	18	18
Continuous improvement	55	55	59	61	71	53	65	59
Process benchmarking	31	30	40	27	46	29	40	34
Process simulation	11	11	25	11	30	12	23	16
Process value-added analysis	18	22	24	28	32	29	26	25
Other	1	2	1	1	1	3	–	1

Two-thirds of all plants use at least one of these nine product and process practices, and 28% used four or more (Table 8A). However, they are less likely to be used alone than the other practices (Table 8D).

Given its high ranking among product quality practices, it is not surprising that continuous improvement is the practice most often applied to technology development; it is used by 59% of all plants. Process benchmarking is the second most popular practice at 34%, followed by quality function deployment and process value-added analysis, both of which are used by about a quarter of all plants. The practices that are most closely associated with advanced technology use are the least commonly employed—rapid prototyping, computer-aided design, process simulation and concurrent engineering.

Compared with the other two categories of business practices, there is somewhat more variation in the adoption rates of product and process development practices within industries and across industries. The fruit and vegetable, and "other" industries are again above average in their adoption rate. Dairy tends to reflect the industry average, while the cereal, bakery, meat and fish industries tend to be below average in their use of these practices.

8.2 Relationship to Plant Size

Larger plants are much more likely to use at least one practice from each of the three categories of business practices than are the smaller plants. In particular, 80% of plants with 250 or more employees use at least one practice from each group, compared with 35% of those with 10 to 19 employees. The percentages for the 20-to-49, 50-to-99, and 100-to-249 employee-size groups are 51%, 58% and 64%, respectively.

The most frequently used practices in each of the three categories are the same for all size groups. However, the frequency of use of almost all the practices is strongly related to plant size. This is especially true for the largest and smallest size groups, and between them and their respective adjoining size group. The rate at which use increases with plant size varies appreciably by practice. The relationship between

Table 8E: Use of Business Practices by Size Group

	Employment size group					
	10 - 19	20 - 49	50 - 99	100 - 249	250+	All
	percentage of establishments					
Product Quality Practices						
Continuous quality improvement (CQI)	70	76	76	81	89	77
Benchmarking	38	43	43	52	79	47
Acceptance sampling	73	73	77	80	87	76
Certification of suppliers	45	51	61	67	77	57
Good manufacturing practices (GMP)	76	78	80	86	92	81
Hazard analysis critical control points (HACCP)	40	60	69	78	93	64
Food safety enhancement program (FSEP)	38	49	52	54	69	50
Plant quality certification	15	15	29	33	32	23
Other	4	7	7	6	15	7
Materials and Distribution Management Practices						
Materials requirement planning (MRP)	32	49	50	55	73	49
Manufacturing resource planning (MRPII)	20	32	37	36	55	33
Process changeover time reduction	23	35	48	45	58	39
Just-in-time inventory control	43	51	57	55	59	52
Electronic work order management	13	16	20	26	39	20
Electronic data interchange	12	18	31	40	70	29
Distribution resource planning	9	18	24	21	50	21
Other	1	–	–	3	–	1
Product and Process Development Practices						
Rapid prototyping	5	13	17	15	24	13
Quality function deployment	13	24	30	32	46	26
Cross-functional design teams	7	12	21	23	44	18
Concurrent engineering	6	11	15	21	38	16
Computer-aided design (CAD)	6	11	18	22	56	18
Continuous improvement	43	57	58	69	85	59
Process benchmarking	25	25	37	37	66	34
Process simulation	10	14	17	20	28	16
Process value-added analysis	14	23	26	29	50	25
Other	3	1	–	1	2	1

adoption rates and size appears to be somewhat stronger for materials and distribution management practices and for product and process development practices than for product quality practices (Table 8F).

Within groups, differences exist in the degree to which incidence is related to size. In some cases, there is a relatively small difference between small and large (for example, continuous quality improvement and acceptance sampling); in others, the difference is large (for example, hazard analysis and benchmarking).

In some cases, large size-class differences are associated with a high incidence of use by large plants. These, then, are practices that large plants have learned to master, which suggests that the practices are relatively mature. The fact that small plants have not yet put them into practice indicates that some other factor, such as applicability or cost, lies behind these differences. Examples of practices that fall into this category are hazard analysis and electronic data interchange.

In other cases, although differences across size classes are large, incidence of use by even large plants is not high. These are situations where even large firms have not yet learned to apply the practices, which may mean that the practices are relatively new and not yet mature. This applies to electronic work order management and distribution resource planning.

8.3 Differences by Country of Control

Foreign-controlled plants are more likely to adopt these advanced business practices than are Canadian-controlled plants. Eighty percent of foreign-controlled plants use at least one practice from each of the three categories, compared with 50% of Canadian-controlled plants.

The greater use of these practices by foreign-controlled firms applies to all practices except FSEP. For cross-functional design teams, computer-aided design, distribution resource planning and electronic data interchange, use by foreign-controlled plants is at least twice as high as by Canadian-controlled plants. In some other cases, the difference is much smaller; as is the case for good manufacturing practices, continuous quality improvement, acceptance sampling, and process value-added analysis (Table 8F). The practices with the largest differentials are among those whose incidence of use is most closely related to size, while those with the smallest differentials are less closely related to size.

8.4 Summary and Conclusions

The implementation of broad business objectives involves the adoption of appropriate business practices. This study investigates the use of practices in the areas of product quality, materials and distribution management, and product and process development. Over half of all plants in the food-processing industry use at least one practice from each of these three areas.

The incidence of use of these practices is related to the industry's strategic priorities. Practices that are aimed at enhancing product quality (which includes food safety) are used the most frequently. The second highest level of use is in the materials and distribution management area, which contributes to productivity and improves a firm's ability to respond to customer needs. Product and process development practices rank third in use. Consistent with the emphasis that is given to the strategy of incremental improvement of technology, the most common practice in the product and process development area is that of continuous improvement.

The incidence of practices varies across industries. The fruit and vegetable, "other" and dairy industries tend to be the leading users of all three types of business practices. On the other hand, the bakery and meat industries tend to be below average.

Table 8F: Use of Business Practices by Country of Control

Practice	Country of Control		
	Canada	Foreign	All
	percentage of establishments		
Product quality practices			
Continuous quality improvement	76	86	77
Benchmarking	45	65	47
Acceptance sampling	75	89	76
Certification of suppliers	54	80	57
Good manufacturing practices	80	91	81
Hazard analysis critical control points	62	78	64
Food safety enhancement program	50	48	50
Plant quality certification	21	38	23
Other	7	9	7
Materials and distribution management practices			
Materials requirement planning	47	64	49
Manufacturing resource planning	32	46	33
Process changeover time reduction	35	66	39
Just-in-time inventory control	51	60	52
Electronic work order management	19	33	20
Electronic data interchange	26	55	29
Distribution resource planning	19	39	21
Other	1	2	1
Product and process development techniques			
Rapid prototyping	13	19	13
Quality function deployment	26	32	26
Cross-functional design teams	15	39	18
Concurrent engineering	14	27	16
Computer-aided design	16	32	18
Continuos improvement	57	79	59
Process benchmarking	31	55	34
Process simulation	15	27	16
Process value-added analysis	25	32	25
Other	1	1	1

The incidence of use of most practices is strongly related to plant size. Although the three leading practices are the same for all size groups, the level of use and the strength of the use-to-size relationship differ appreciably among the practices. In those cases where the difference is large, the reasons could include the age, applicability and cost of the practice. The relationship to size is somewhat weaker for the product quality practices than the other two sets, which reflects the importance of quality in the business strategies of all firms.

Foreign-controlled plants are much more likely to use these advanced practices than are Canadian-controlled plants. The largest differences in use here are associated with those practices most strongly related to the size of plant.

Chapter 9 – Advanced Technologies

The process innovations and the business practices described in the previous two chapters require new technologies and techniques in order to meet strategic objectives related to product quality enhancement and cost reduction. This chapter examines the nature of the technologies that have been incorporated into food processing. For the purposes of this study, nine functional areas were investigated: processing, process control, quality control, inventory and distribution, management and information systems and communications, materials preparation and handling, pre-processing activities, packaging, and design and engineering.

This chapter is divided into two main sections. The first describes the advanced technologies examined in this study and their rates of adoption. A brief overview of the use of advanced technologies is followed by a more detailed discussion of the individual technologies and their use, grouped by functional area, both overall and at individual industry levels. Succeeding sections relate technology use to size of plant, country of control and stage of processing, respectively. The second section employs multivariate statistical analysis to examine the separate effects of these and other plant characteristics on technology use.

The use of advanced technologies is measured in terms of incidence, intensity and comprehensiveness.

Incidence is used to describe whether an establishment employs a particular technology. It is also applied to a group of technologies (for example, those from a specific functional area) where it refers to the use of at least one of the technologies from the collection of technologies being studied. It does not indicate the number of technologies being used.

Intensity is used here to describe how many advanced technologies overall are being used within an establishment. It is also used to indicate the number of technologies from a functional technology group that are being used. The greater the number of technologies used, the greater the intensity of use.

Comprehensiveness is used to describe the extent to which a plant uses advanced technologies from more than one functional area.

9.1 Adoption Rates

9.1.1 Overview of adoption rates by industry

The incidence of advanced technology use is high in the food industry with 88% of establishments using at least one of the 61 advanced technologies identified in the survey questionnaire. The incidence of use ranges from 82% in the fish products industry to 95% in the "other" food products industry (Table 9A).

There is considerable variation in the intensity of use. While 88% use at least one technology, 54% use more than five technologies, 29% use more than 10, and only 7% use more than 20. There were substantial differences in intensity of use among the industries. In particular, about 21% of the plants in the dairy industry use more than 20 new technologies, compared with the food industry average of 7%. Also, a third of the plants in the fruit and vegetable and "other" industries use 11 to 20 technologies, well above the food-industry average of 22%. On the other hand, the bakery and fish industries tend to use relatively few of the technologies identified in this study. Fifty-two percent of the bakery industry's plants reported using only one to five technologies compared with the food industry average of 34%.

9.1.2 Use by functional area and individual technology

The adoption rates of new technologies should depend upon company objectives and the availability of new technologies that are better able to meet plant needs than existing technologies. This section discusses technology use in the context of a plant's functions and, in broad terms, the contribution of each technology to plant operations. Differences by industry are included in this section and then summarized in the multivariate analysis section. Relationships to plant size, control, stage of processing and business strategies are discussed in succeeding sections.

An overview of the incidence of advanced technology use by each of nine functional areas is provided in Table 9B. Plants are most likely to use at least one technology from the processing and communications

Table 9A: Number of Advanced Technologies Used by Industry

Industry	Number of advanced technologies None	1 - 5	6 - 10	11 - 20	20+	At Least 1
	percentage of establishments					
Bakery	17	52	17	12	2	83
Cereal	13	37	26	20	4	87
Dairy	5	28	24	22	21	95
Fish	18	31	31	17	3	82
Fruit and Vegetables	7	32	18	33	10	93
Meat	16	23	33	21	6	84
Other	5	34	23	31	7	95
All	12	34	25	22	7	88

Table 9B: Technology Use[a] by Functional Area by Industry

Functional area	Bakery	Cereal	Dairy	Fish	Fruit and Vegetables	Meat	Other	All
	percentage of establishments							
Processing	50	44	77	70	73	67	61	62
Process control	46	58	77	40	67	54	63	56
Quality control	22	41	69	46	44	44	52	44
Inventory and distribution	31	28	36	32	39	52	49	39
Management systems/communications	54	71	67	50	64	55	75	62
Materials preparation and handling	27	43	33	26	34	26	31	31
Pre-processing	13	42	55	36	39	38	38	36
Packaging	38	32	67	43	59	56	65	51
Design and engineering	11	22	23	15	26	22	23	20

[a] Percentage of establishments using at least one technology in a functional group.

groups. Sixty-two percent use at least one technology from each of these areas followed by process control (56%) and packaging (51%). The incidence of use is lower for materials preparation and handling, and design and engineering.

Individual industries differ somewhat in the incidence of use of advanced technologies by functional area. For example, the fruit and vegetable, dairy and "other" industries are average or above for all areas. On the other hand, the bakery industry is below the food-industry average for virtually all functional groups, and the fish industry is below average for slightly more than half (Table 9B). These findings confirm the previous result that was based on the use of any one advanced technology.

With respect to comprehensiveness of use, most plants use advanced technologies from a number of different functional areas (Table 9C). Some 88% use technologies from at least one functional area, while only 18% use advanced technologies from seven or more of the nine areas. Sixty percent use at least one technology from some combination of two to six functional areas. Like the other measures of technology use, comprehensiveness of use varies substantially across industries. For example, 26% of plants in the "other" and 31% of plants in the dairy industry use advanced technologies from seven or more functional areas, while only 11% of fish plants and 6% of bakery plants do so.

The effectiveness of new technologies is partly related to the way they are combined with other new (and existing) technologies. For example, 52% of plants use at least one advanced technology in four or more functional areas (Table 9C). Nineteen percent use at least one technology in each of the four "online" production activities of pre-processing, processing, process control and packaging, while 13% use this combination along with a local area network (LAN). Also, 15% use at least one technology in both of the functional areas associated with moving and storing inputs and products—materials preparation and handling, and inventory and distribution—10% with a LAN. Six percent use advanced technologies in both the production and "logistical" areas as well as a local area network.

Table 9C: Adoption of Advanced Technologies by Number of Functional Areas by Industry

Number of functional areas	Bakery	Cereal	Dairy	Fish	Fruit and Vegetables	Meat	Other	Total
	percentage of establishments							
All 9 areas	1	4	12	–	3	8	2	4
8 or more	5	8	20	5	9	15	13	11
7 or more	6	14	31	11	20	21	26	18
6 or more	14	25	49	21	41	28	34	28
5 or more	20	35	56	33	53	46	46	40
4 or more	31	51	66	45	59	59	59	52
3 or more	49	63	82	63	72	69	79	67
2 or more	69	75	87	70	84	77	89	78
1 or more	83	87	95	82	93	84	95	88

9.1.2.1 Processing

Processing is central to all activities in a plant. It involves transforming ingredients into food products that are attractive with respect to nutritional content, flavour, texture, appearance, convenience and shelf life. Just as importantly, the processing technique must yield a product that is safe to eat and competitively priced. New processing technologies attempt to meet and balance these multiple goals.

Twenty advanced processing technologies were identified in the survey questionnaire. These were grouped into five functional sub-areas: thermal preservation; non-thermal preservation; separation, concentration, and water removal; additives and ingredients; and "other" processing technologies.

Sixty-two percent of establishments use at least one of the 20 advanced technologies in this functional area. The incidence of use is highest in the dairy, fruit and vegetable and fish industries, where 77%, 73% and 70% of establishments use at least one advanced processing technology, respectively. The meat industry is not far behind at 67%, while the "other" industry is average. The bakery and cereal industries are relatively light users of the advanced processing technologies identified in this study, with 50% and 44% of establishments using at least one of these technologies, respectively (Table 9D).

These industry differences in incidence of use could be caused by several factors. One factor is differences in the applicability of these technologies—processing technologies such as deep-chilling and bio-ingredients are applicable to a limited number of product lines. This factor would also explain some of the differences in the incidence of use by processing sub-area and individual technology.

Among the functional sub-areas, the non-thermal preservation group has the highest incidence of use. The characteristics and adoption rates of advanced technologies by sub-group are as follows.

Thermal preservation. These technologies use heat to transform, sterilize or pasteurize food products. New thermal technologies have advantages over traditional methods such as lower or shorter-time processing temperatures that improve product quality (such as taste, texture, and appearance). They also allow packaging better tailored to buyer needs.

Five advanced technologies were identified in this sub-area. *Aseptic processing or packaging* involves putting a sterile product into a sterile package that is hermetically sealed—all of which is done in a sterile environment. *Retortable flexible packages* use polymeric film laminates in a flat pouch design that allows products to be sterilized in a flexible, convenient package. The other three thermal technologies are infra-red, ohmic and microwave (or other high frequency) heating. *Infra-red heating* uses radiant energy to heat surfaces, *ohmic heating* involves passing an electric current through the product, and *microwave heating* uses microwave ovens.

Twenty-six percent of food-industry plants use at least one of these advanced thermal-processing technologies. Aseptic processing or packaging is used by 14% of firms and retortable flexible packages are used by 9%. Five percent or less use infra-red, ohmic, microwave or other advanced heating methods.

The dairy and fruit and vegetable industries are the major users of these thermal technologies. In both industries, 41% use at least one, and aseptic processing is used by roughly one-third. Advanced thermal technologies are used by few plants in the cereal

Table 9D: Incidence of Use of Advanced Processing Technology by Industry

Technology	Bakery	Cereal	Dairy	Fish	Fruit and Vegetables	Meat	Other	Total
				percentage of establishments				
PROCESSING	50	44	77	70	73	67	61	62
1. *Thermal Preservation*	17	11	41	21	41	31	29	26
a) aseptic processing	7	1	35	11	30	18	12	14
b) retortable flexible packages	6	–	10	8	13	12	13	9
c) infra-red heating	1	3	8	1	3	1	3	3
d) ohmic heating	–	1	–	1	3	1	–	1
e) microwave heating	6	1	5	3	4	3	6	4
f) other	4	4	6	4	7	6	5	5
2. *Non-thermal Preservation*	32	16	34	65	54	52	26	39
a) chemical antimicrobials	8	9	19	13	32	21	17	16
b) ultrasonic techniques	1	–	–	–	–	4	4	2
c) high pressure sterilization	2	8	15	16	13	10	4	9
d) deep chilling	27	1	19	51	24	40	11	25
e) other	1	–	1	8	8	2	2	3
3. *Separation, Concentration and Water Removal*	12	19	49	31	38	35	35	30
a) membrane process	–	1	21	5	13	3	5	5
b) filter technologies	4	7	23	12	22	17	21	15
c) centrifugation	–	2	40	8	12	6	13	10
d) ion exchange	–	1	6	1	8	1	4	3
e) vacuum microwave drying	–	–	–	5	1	2	–	1
f) water activity control	10	12	14	23	20	21	14	16
g) other	–	2	1	2	–	2	1	1
4. *Additives and Ingredients*	17	28	50	9	11	17	14	19
a) bio-ingredients	15	28	33	6	10	9	8	14
b) microbial cells	4	6	29	2	3	9	6	8
c) other	–	1	4	4	–	2	3	2
5. *Other*	–	1	6	2	2	3	2	2
a) electrotechnologies	–	1	5	2	2	2	–	1
b) microencapsulation	–	–	1	–	–	1	2	1
c) other	–	–	1	1	–	1	–	1

and bakery industries, where more traditional methods are effective in meeting product requirements.

Non-thermal preservation. Where applicable, these technologies make food safe to eat and extend shelf life while avoiding undesirable effects on product quality caused by thermal processing methods. In some cases, they may be used in combination with other preservation technologies.

Four technologies or groups of technologies were identified in this sub-area: chemical antimicrobials, ultrasonic techniques, high-pressure sterilization and deep-chilling techniques. *Chemical antimicrobials* occur naturally or are added during processing to prevent or interfere with microbial growth. *Ultrasonic techniques* employ an ultrasonic power field to physically disrupt or transform globular proteins. *High-pressure sterilization* uses extremely high hydrostatic pressure to sterilize or pasteurize certain food products. *Deep chilling* is the process by which food products such as meat and fish are cooled to just above their freezing point.

As a group, these are the most commonly used advanced processing technologies, with 39% of plants using at least one. By far, the most widely used are deep chilling (25%) and chemical antimicrobials (16%). Very few plants use ultrasonic techniques.

About half the plants in the fish industry and 40% of meat plants use deep chilling. The fruit and vegetable industry is the largest user of chemical antimicrobials (32%). Not surprisingly, the cereal industry is the least likely to use these non-thermal preservation methods.

Separation, concentration and water removal. A common requirement in food processing is the separation and/or concentration of the constituent components of raw products, including the removal or neutralization of their water content. The six technologies identified in this functional area are advanced membrane processes, filter technologies, centrifugation, ion exchange, vacuum microwave drying and water activity control.

New *membrane processes* use advanced membranes and processes that are pressure-activated to separate or concentrate substances without a phase change (liquid to solid). *Filter technologies* such as tangential filtration and ultrafiltration are used to fractionate, separate or concentrate substances without a phase change and they also rely on advanced membrane technology. *Centrifugation* accomplishes these same results, using high-speed centrifuges (such as ultracentrifugation). *Ion exchange* replaces chemicals in fluids (for example, nitrates in wastewater) with other ions. *Vacuum microwave drying* removes water from products such as potatoes and fruit, while maintaining quality. *Water activity control* is a process for neutralizing rather than removing the water content of a product.

Thirty percent of food-industry plants use at least one of these technologies. The most commonly used are water activity control (at 16% of plants) and filter technologies (15%). Centrifugation and membrane processes are employed by 10% and 5% of all plants, respectively. Very few use ion exchange or vacuum microwave drying.

The industry with the highest incidence of usage of these technologies is the dairy sector where [illegible] of plants use at least one; 40% use centrifugation, and about 22% use filter technologies and/or membrane processes. Only the bakery and cereal industries, with incidence rates of 12% and 19%, respectively, are below the overall industry average of 30%. Water activity control is the most uniformly used across industries, and is the most important one in several of them. Significant numbers of plants in most industries also use filter technologies.

Additives or ingredients. A range of additives and ingredients are used to enhance the flavour, colour and aroma of processed foods. New technologies include *bio-ingredients* that have been modified (for example, restructured or immobilized enzymes) to avoid or control undesirable effects, and *microbial cells*, a natural form of immobilized enzymes with desirable properties.

Nineteen percent of all plants use at least one of these technologies, with 14% using bio-ingredients, 8% microbial cells, and 2% some other kind.

The dairy industry is the leading user of these technologies; 50% use at least one, with 33% using bio-ingredients and 29% microbial cells. The large difference between the percentage of firms using at least one and the percentage using each of the two individual technologies indicates that relatively few use both. This is a common result for these technologies across industries. The cereal industry is also above average, with 28% using at least one technology, mainly bio-ingredients. Plants in the fish and fruit and vegetables industries are the least likely to use these additives or ingredients.

Other processing technologies. The "other" group is comprised of electrotechnologies and microencapsulation.[16] *Electrotechnologies* use electricity to control acidity and oxidation, and inactivate harmful bacteria, yeasts and moulds. *Microencapsulation* immobilizes enzymes, cells or other molecular species by covering them with an extremely thin coating. Only 2% of food-industry plants use at least one of these technologies.

9.1.2.2 Process control

Accurate and timely control of all aspects of the processing activity (such as temperature and pressure) is essential to ensure product quality, safety and efficient operation. While advanced devices used in process control, such as vision systems, can use a range of technologies, they often use computers and are connected to a computerized information or control system. Such control technologies are a key element of process automation.

Six process control technologies were included in the survey. *Automated sensor-based equipment* incorporates technologies capable of measuring a variety of food properties (such as colour, moisture and weight) of incoming or in-process products. *Automated statistical process control* compares real-time process data against statistical performance standards. *Machine vision* uses image-processing methods to identify a digital image of an object to determine whether any control action should be taken. This allows for the online inspection of every

[16] Irradiation was included in this group on the questionnaire but is not reported here because the responses were found to be inaccurate during post-production testing.

Table 9E: Incidence of Use of Advanced Process Control Technology by Industry

Technology	Bakery	Cereal	Dairy	Fish	Fruit and Vegetables	Meat	Other	Total
	percentage of establishments							
PROCESS CONTROL	46	58	77	40	67	54	63	56
a) automated sensor-based equipment for inspection/testing	17	19	31	16	31	19	28	22
b) automated statistical process control	11	12	21	12	19	12	13	14
c) machine vision	6	10	10	9	27	5	8	9
d) bar coding	11	9	23	17	25	30	18	19
e) programmable logic controllers	29	37	62	12	49	29	49	36
f) computerized process control	22	46	56	19	35	24	31	32
g) other	3	3	1	1	2	3	1	2

item. *Bar-coding* is used to identify ingredients being handled on the processing line and can be part of the automation process. *Programmable logic controllers* are solid-state industrial control mechanisms that are used as switching devices. In *computerized process control*, computers are used to continually monitor and adjust parts of the production process in order to maintain overall performance standards.

With 56% of plants using at least one of these technologies, process control ranks third among the nine functional areas. Programmable logic controllers and computerized process control are each used by roughly one-third of the plants in the industry, while 22% use automated sensor-based equipment, and 19% use bar-coding. The least used of this group are automated statistical process control and machine vision—at 14% and 9%, respectively (Table 9E).

The leading users of process-control technologies are the dairy, fruit and vegetables, and "other" industries with 77%, 67% and 63% of establishments, respectively, using at least one of them. These three industries are particularly strong users of programmable logic controllers and automated sensor-based equipment. The dairy and cereal industries are leaders in the use of computerized process control, with 56% and 46% of establishments using it, respectively.

Advanced process-control technologies are least commonly used in the fish and bakery industries, but even so, 40% of plants in the fish industry and 46% in the bakery industry use at least one of them.

9.1.2.3 Quality control

Quality control in a food-processing plant ensures that final products meet expectations with respect to quality characteristics such as flavour, texture and appearance. These are characteristics that are difficult to measure because of their subjective nature. Quality control is also the functional area responsible for meeting firm and regulatory food safety standards with respect to microbial and chemical contamination. Quality control involves testing for these several product characteristics. It also extends to establishing specifications for and testing raw materials or ingredients, instructing and supervising employees on quality-related matters, and record keeping.

Three types of quality control techniques are process testing, laboratory testing and simulation.

Process testing. Of the six advanced technologies identified, four are process or product-testing technologies—chromatography, monoclonal antibodies, DNA probes, and rapid-testing techniques. The other two are automated laboratory testing and mathematical modelling of quality or safety. *Chromatography* involves separating mixtures into their constituent elements; *monoclonal antibodies* is a process that refers to the production of a homogenous population of antibodies; *DNA probes* are used to identify specific organisms; while *rapid-testing techniques* are relatively quick and simple microbiological and chemical tests.

Laboratory testing. *Automated laboratory testing* refers to the automation of functions performed in the laboratory.

Simulation. *Mathematical modelling of quality or safety* is the use of simulation techniques to identify the possible quality and safety implications of proposed new processes.

Forty-four percent of all plants use at least one advanced quality control technology. Twenty-nine percent use at least one process-testing technology, with

Table 9F: Incidence of Use of Advanced Quality Control Technology by Industry

Technology	Bakery	Cereal	Dairy	Fish	Fruit and Vegetables	Meat	Other	Total
				percentage of establishments				
QUALITY CONTROL	22	41	69	46	44	44	52	44
1. *Process Testing*	14	20	63	18	32	31	37	29
a) chromatography	2	6	9	–	6	4	12	6
b) monoclonal antibodies	–	1	9	2	6	4	3	3
c) DNA probes	1	1	2	1	2	1	–	1
d) rapid testing techniques	10	18	56	14	26	26	30	24
e) other	3	–	2	3	3	3	5	3
2. *Laboratory Testing*	11	29	34	26	21	25	28	25
a) automated	4	14	25	8	10	14	18	13
b) other	7	18	10	20	14	15	13	14
3. *Simulation*	6	7	9	12	12	5	5	7
a) mathematical modelling of quality or safety	5	6	8	11	12	5	5	7
b) other	1	1	1	1	–	–	–	1

rapid-testing techniques (24% of plants) being by far the most commonly used. Twenty-five percent use an advanced laboratory technology. Only 7% of establishments use mathematical simulation methods (Table 9F).

The highest incidence of use of advanced quality control technologies is by the dairy industry (69%), followed by the "other" food products industry (52%). Only 22% of bakery plants use at least one. Despite this difference in the percentage of plants using at least one, the relative incidence of use of individual technologies was much the same across industries. The exceptions are relatively greater use of chromatography by the "other" industry (12%) and monoclonal antibodies (9%) and automated laboratory testing (25%) by the dairy industry, and of other laboratory testing methods by the fish and cereal industries (20% and 18%, respectively).

9.1.2.4 Inventory and distribution

Advanced inventory and distribution technologies are associated with the automation of these functions. *Bar-coding*, now a familiar sight on retail packages, provides for electronic identification and is used to locate and monitor inventories of inputs and outputs. *Automated product handling* is an automated storage and retrieval system based on the use of radio frequencies.

At least one of these technologies is used by 39% of food-industry plants; 34% use bar-coding and 11% report an automated product handling system. Bar-coding is most commonly used by the meat and "other" industries, but is little used in the cereal industry. On the other hand, the cereal industry, along with the fruit and vegetable industry, is a leading user of automated product handling (Table 9G).

9.1.2.5 Management and information systems and communications

New information technologies have revolutionized management information and communications systems. They allow instantaneous access to detailed information. *Local area networks (LANs)* connect computers within establishments. They allow the exchange of data between management, the factory floor and different departments. *Wide area networks (WANs)* connect computers located in different plants and offices of the same firm. *Inter-company computer networks* connect establishments to subcontractors, suppliers and customers. The *Internet or World Wide Web* can be used for *marketing and promotional activities,* or for *facilitating plant operations* such as procurement, point-of-sale data, research, and hiring.

Sixty-two percent of food-industry plants employ at least one of these five information technologies. The most common are local area networks (used by 43% of plants) and inter-company computer networks (used by 37%), which indicates their importance as management tools. The least commonly used, at 20%, are wide area networks. Considering that most firms in the industry have a single establishment, this latter result is not surprising (Table 9H).

Table 9G: Incidence of Use of Advanced Inventory and Distribution Technology by Industry

Technology	Bakery	Cereal	Dairy	Fish	Fruit and Vegetables	Meat	Other	Total
	percentage of establishments							
INVENTORY AND DISTRIBUTION	31	28	36	32	39	52	49	39
a) bar coding	28	16	32	28	35	48	43	34
b) automated product handling	6	15	11	7	17	10	12	11
c) other	0	1	3	3	2	2	3	2

Table 9H: Incidence of Use of Advanced Management Systems and Communications Technology by Industry

Technology	Bakery	Cereal	Dairy	Fish	Fruit and Vegetables	Meat	Other	Total
	percentage of establishments							
MANAGEMENT AND INFORMATION SYSTEMS AND COMMUNICATIONS	54	71	67	50	64	55	75	62
a) local area network	36	51	45	27	51	38	55	43
b) wide area network	19	20	30	11	23	15	29	20
c) inter-company computer networks	30	44	49	28	38	36	40	37
d) Internet–marketing and promotion	19	29	23	29	26	27	35	27
e) Internet–other	13	31	25	30	23	19	42	27
f) other	1	4	–	1	3	2	1	1

At the industry level, the "other" and cereal industries are the greatest users, with 75% and 71% of plants, respectively, using at least one of the advanced technologies in this area. Compared with the food industry as a whole, these two industries are average or above average in the use of all information technologies. Along with the fruit and vegetable industry, they are the leading users of local area networks. While only 50% of fish industry plants use at least one of the information technologies, the industry is essentially average in its use of the Internet or World Wide Web for both marketing or promotional purposes, and operations.

9.1.2.6 Materials preparation and handling

Materials preparation and handling technologies are used for manipulating and moving raw materials and products. *Integrated electronically controlled machinery* are electronically guided vehicles used for transporting materials and products across the "shop floor". *Individual electronically controlled non-integrated machinery* refers to machinery such as robots that are reprogrammable, multifunctional manipulators of materials, parts, tools and specialized devices. The *electronic detection of machinery failure* involves the use of electronic sensors to immediately locate the source of mechanical problems.

Thirty-one percent of plants in the food industry use at least one of these three technologies. Ten percent use each type of machine, while 23% use electronic means to detect machine failure. The cereal industry is the leading user of these technologies. However, there is relatively little variation in incidence of use among industries (Table 9I).

9.1.2.7 Pre-processing

The quality of finished products is largely dependent on the quality of raw and semi-processed products. In turn, this depends on such factors as the way products were produced, transported and handled at the plant. Advanced technologies in this area were classified as those that contribute to the quality enhancement of raw products and those that contribute to the quality assessment of raw products.

Raw-product quality enhancement Three technologies were identified in the quality enhancement group: *animal stress reduction* improves meat quality and is accomplished through using methods such as gases that render an animal unconscious prior to slaughter, rather than an electrical charge; *bran removal before milling wheat* uses methods such as friction, abrasion and soaking; and *micro component separation* involves the separation of elements such as proteins for use in other products.

Table 9I: Incidence of Use of Advanced Materials Preparation and Handling Technology by Industry

Technology	Bakery	Cereal	Dairy	Fish	Fruit and Vegetables	Meat	Other	Total
				percentage of establishments				
MATERIALS PREPARATION AND HANDLING	27	43	33	26	34	26	31	31
a) integrated electronically controlled machinery	13	12	8	8	8	9	11	10
b) individual electronically controlled non-integrated machinery	8	10	14	10	11	10	11	10
c) electronic detection of machinery failure	16	39	26	20	27	18	21	23
d) other	–	–	1	–	1	1	–	–

Raw-product quality assessment. The quality assessment technologies were six in number: *electronic or ultrasonic grading,* which is used for the non-invasive measurement of carcass fat; *collagen, colour or PSE probe,* the first of which is used to measure the tenderness of meat and the second and third are used for measuring muscle and fat levels; *near infra-red (NIR) analysis* is used to measure moisture, fat and protein; *colour assessment or sorting* is used where quality characteristics (such as ripeness) are related to colour, and colour is detected electronically; *electromechanical defect sorting* involves the electrical identification of defects; and *rapid-testing techniques* identify pesticide and microbiotic residues, contamination and spoilage.

Just over one-third of plants (36%) use at least one of these pre-processing technologies. Only 6% use at least one of the raw-product enhancement technologies, while 34% use at least one of the quality assessment technologies. By far, the two most commonly used technologies are rapid testing and colour assessment or sorting, with 19% and 17% of plants using them, respectively. Nine percent or less of the plants use all other technologies (Table 9J).

Most of these pre-processing technologies are specific to an industry or product, and this is reflected in their rates of adoption by the food industry as a whole and by an individual industry. Not surprisingly, the bakery industry, which uses mostly processed or semi-processed products has the lowest incidence of use (13%). The dairy industry is the greatest user, with 55% using at least one of these advanced technologies, but this is largely because about half its plants use rapid-testing techniques. As well, 30% of dairy plants use near infra-red analysis for raw-product quality assessment.

9.1.2.8 Packaging

Packaging is used to protect food products from contamination and spoilage and to permit convenient handling. It is also used to convey information to the buyer and to sell the product. Seven packaging technologies are classified into three sub-groups—equipment, preservation and advanced materials.

Overall, the set of packaging technologies identified in this study ranked fourth in incidence of use, with 51% of plants using at least one of the seven identified. At the individual industry level, the leading users of packaging technology are the dairy, "other", fruit and vegetable and meat industries (Table 9K). Fifty-five percent or more of the plants in each of these industries use at least one of the advanced technologies. In contrast, the incidence of use by the cereal, bakery and fish plants is below the food-industry average.

Equipment. Automated-packaging equipment is used to reduce costs and add operating flexibility. *Integrated electronically controlled equipment* and *non-integrated electronically controlled equipment* are two types of advanced packaging technologies. Both types are electronically controlled; the integrated version is linked to a central computer.

Thirty-five percent of plants used at least one of these two technologies; 29% used non-integrated equipment, and 15% used the integrated type. While a significant number of plants in all industries employ each type, the dairy, fruit and vegetable and "other" industries are the leading users.

Table 9J: Incidence of Use of Advanced Pre-processing Technology by Industry

Technology	Bakery	Cereal	Dairy	Fish	Fruit and Vegetables	Meat	Other	Total
				percentage of establishments				
PRE-PROCESSING ACTIVITIES	13	42	55	36	39	38	38	36
1. *Raw Product Quality Enhancement*	3	13	3	5	–	14	3	6
a) animal stress reduction	–	–	–	2	–	14	1	3
b) bran removal before milling wheat	2	8	–	–	–	–	2	2
c) micro component separation	1	3	3	–	–	–	1	1
d) other	1	2	–	3	–	–	–	1
2. *Raw Product Quality Assessment*	12	37	54	34	39	32	38	34
a) electronic or ultrasonic grading	1	4	5	6	7	6	1	4
b) collagen, colour or PSE probe	1	2	–	6	2	6	4	3
c) near infra-red analysis	1	19	30	1	1	4	10	9
d) colour assessment or sorting	6	19	10	20	30	17	20	17
e) electromechanical defect sorting	1	3	4	4	12	3	5	4
f) rapid testing techniques	5	16	50	9	18	25	21	19
g) other	3	4	4	5	1	1	1	3

Table 9K: Incidence of Use of Advanced Packaging Technology by Industry

Technology	Bakery	Cereal	Dairy	Fish	Fruit and Vegetables	Meat	Other	Total
				percentage of establishments				
PACKAGING	38	32	67	43	59	56	65	51
1. *Equipment*	27	23	49	29	50	29	47	35
a) non-integrated electronically controlled packaging machinery	23	20	43	26	38	26	36	29
b) integrated electronically controlled packaging machinery	11	11	21	9	27	10	24	15
2. *Preservation*	11	2	29	14	18	39	15	18
a) modified atmosphere	11	2	29	14	18	39	15	18
3. *Advanced Materials*	16	23	44	25	28	35	49	32
a) laminates	7	8	30	12	17	24	28	18
b) active packaging	5	1	4	10	8	3	7	5
c) multi-layer	9	21	36	12	22	26	32	22
4. *Other*	–	–	–	–	–	–	–	–

Preservation. Only one "preservation" packaging technology was identified in the survey questionnaire, namely *modified atmosphere packaging*. This type of packaging achieves longer shelf life without using chemical or physical treatments by replacing the initial atmosphere in the package.

This technology was used by 18% of all plants. It is most widely used by meat plants (39%) and dairy plants (29%). It has little application to the cereal industry.

Advanced materials. Three types of advanced packaging materials are laminates, active packaging, and multi-layer. *Active packaging* uses materials that contain or produce bacterial inhibitors to retard food deterioration. *Laminates* are a single wrapping of

layers of materials. Each layer has different properties that are used to regulate the transmission of oxygen, light and moisture. *Multi-layer* refers to the use of more than one wrapping layer, each of which has differing transmission properties. For example, one layer could be removed to allow changes in the product before display at retail.

About a third of all plants use at least one of these materials, with 22% using multi-layer, 18% laminates and only 5% active packaging. Although this ranking of types of materials used applies to almost all the industries, their relative incidence differs substantially. In particular, nearly half the "other" and dairy plants use at least one of these materials. This compares with only average use by the meat and fruit and vegetable industries and below average use by the bakery, cereal and fish industries.

9.1.2.9 Design and engineering

Design and engineering are integral parts of product and process development including recipe formulation, simulation and quality control planning. Four types or combinations of advanced technologies were identified in this functional area. *Computer-aided design (CAD)* and/or *computer-aided engineering (CAE):* CAD allows the user to easily produce, alter and store designs, while CAE uses the computer to analyse and test product designs produced by CAD systems. *CAD output used to control manufacturing machines (CAD or CAM):* CAM (*computer-aided manufacturing)* uses the output produced by CAD systems to control the machines that manufacture the part or product. *Computer-aided simulation and prototypes* is the use of computer-based mathematical and physical models to test new products or processes. *Digital representation of CAD output used in procurement activities* is the use of digital CAD output to control a supplier's machines that are used to manufacture the part or product.

Twenty percent of food-industry plants use at least one of these design and engineering technologies. By far, the most commonly used technologies are CAD and/or CAE. At least one of this set is used by 18% of plants, while not more than 5% use any one of the others. This pattern largely holds for all but the bakery industry, in which only 11% of plants use at least one technology and only 9% use CAD and/or CAE (Table 9L).

9.1.2.10 Summary of adoption rates by industry

For the food industry as a whole, the functional areas with the highest incidence of use are processing and management systems and communication technologies, followed closely by process control and packaging. Processing, process control and packaging are all key to the efficient production of quality products. Information technologies, of course, play a critical role in the supervision and management of plant and firm operations. Among functional areas, the incidence of use of quality control and pre-processing technologies is in the mid-to-lower range, as are the rates for the logistical functions of inventory and distribution and materials preparation and handling. The lowest incidence of new technology use is in design and engineering.

We might expect industries to differ in their use of advanced technologies because of the competitive environment or because of differences in the products they produce or their production processes. Factors such as firm size and industry structure may

Table 9L: Incidence of Use of Advanced Design and Engineering Technology by Industry

Technology	Bakery	Cereal	Dairy	Fish	Fruit and Vegetables	Meat	Other	Total
				percentage of establishments				
DESIGN AND ENGINEERING	11	22	23	15	26	22	23	20
a) CAD and/or CAE	9	19	22	15	24	19	20	18
b) CAD/CAM	3	8	4	4	7	5	6	5
c) computer aided simulation and prototypes	–	3	2	2	4	1	7	3
d) digital representation of CAD output used in procurement	–	2	7	1	–	1	3	2
e) other	1	–	2	–	–	1	–	1

also be expected to play a role. For example, technology might be given greater emphasis in industries where technology becomes obsolete rapidly. Similarly, some technologies may be more prevalent in certain industries because the technologies are more suited to some conditions than others. Different processing and packaging technologies are required for liquids than solids, and for perishable than non-perishable products. Also, the need for new technologies can differ because of differences in industry-specific regulatory requirements. This diversity has produced significantly different industry profiles.

Bakery. The bakery industry is well below the food-industry average in its use of the advanced technologies identified in this study. This is indicated by a below average incidence of use for all functional groups, sub-groups, and most individual technologies.

Cereal. The cereal industry is among the leaders in the areas of information technologies, materials preparation and handling, pre-processing and design and engineering. At the same time, it is well below the food industry average in the use of processing, inventory and distribution, and packaging technologies.

Dairy. The dairy industry is the leading user of many of these advanced technologies in terms of incidence and intensity of use. In particular, 20% of plants use 20 or more of them, by far the highest percentage of any industry. It also leads in such areas as processing (except non-thermal preservation) and process-control technologies. It is about average in inventory and distribution as well as materials preparation and handling.

Fish. The fish industry tends to be below average in the use of most technologies but is above average in its use of deep-chilling processing technologies.

Fruit and vegetables. The fruit and vegetable processing industry is the second leading user of advanced technologies. Ten percent of its plants use 20 or more. Its incidence of use is average or above for all functional areas, particularly processing and process control.

Meat. The meat industry is quite consistently around the industry average in its use of these technologies. It is an especially strong user of non-thermal preservation techniques, bar-coding for both process control and inventory and distribution, and modified atmosphere packaging.

Other. The "other" industry is one of the leading users of these new technologies. Ninety-five percent of its plants use at least one advanced technology and 7% use more than 20. Although seldom the top user, its incidence of use is above the industry average for all functional areas. It has the highest incidence of use of information technologies (where it is the leader in the use of the Internet), and advanced packaging materials (along with dairy).

9.1.3 Adoption rates by plant size

Previous manufacturing technology studies have found a strong positive relationship between the rate of adoption of new technologies and the size of establishment (Baldwin and Sabourin 1995). These authors also cite supporting results from earlier studies and note some reasons why larger establishments might be expected to have higher adoption rates for advanced technologies. The reasons identified include better information, greater financial and technical capabilities, and greater ease in identifying opportunities for mechanization or automation when large-scale production processes are being used. The degree to which the size of a plant is a factor in technology use in the food industry is indicated by the following results:

(1) Large plants (250 or more employees) are much more likely to use advanced technologies than small plants (10 to 19 employees). In particular,

- Ninety-seven percent of all plants employing 250 or more people use at least one advanced technology, while 82% of those employing 10 to 19 people do so (Table 9M).

- Thirty-one percent of plants with 250 or more employees use more than 20 advanced technologies, compared with only 1% of those with 10 to 19 employees. Conversely, only 5% of plants in the largest size group report the use of one to five advanced technologies compared with about half the establishments in the smallest size group (Table 9M).

- The largest plants use advanced technologies in more functional areas than the smallest. For example, 57% of plants with 250 or more employees use at least one advanced technology from seven or more areas, compared with only 4% of those employing 10 to 19 people (Table 9N).

- Large plants make greater use of advanced technologies in all functional areas. In four of the nine areas, large plants are at least three times more likely than small plants to use at least one of the advanced technologies, and at least twice as likely to use technologies in eight of the nine areas. The largest difference is in design and engineering where 66% of the 250-and-over employee size group use at least one of the technologies identified in the survey compared with only 7% of the small plants. The smallest difference in adoption rates between the largest and smallest size groups is in processing technologies—88% versus 50% (Table 9O).

- The positive relationship between size and use also applies to the sub-areas, and to almost all individual technologies (see Appendix Table [illegible]). In particular, in both the process testing sub-area of quality control and the raw-product quality assessment sub-area of pre-processing, the largest plants are some four times more likely to use at least one advanced technology than the smallest size plants. The percentage of plants reporting the use of a particular technology is almost invariably higher for the 250-and-over employee size group than the 10-to-19 employee size group.

(2) The positive relationship between size and technology use is also evident across the other size groups.

- The incidence of use by the 20-to-49 employee size group is, for the most part, greater than that of the 10-to-19 employee size group for the functional areas as well as for the functional sub-areas. In addition, the incidence of use by the 250-or-more employee size group was substantially greater than that of the 100-to-249 employee size group for all functional areas and all sub-areas except laboratory testing and simulation (for quality control). In both cases, the incidence of use of the great majority of individual technologies is higher for the larger size group than for the smaller one (Table 9O).

Table 9M: Number of Advanced Technologies Used by Size of Establishment

Employment Size Group	Number of Technologies					
	None	1 - [illegible]	[illegible] - 10	11 - 20	21 +	At Least 1
	percentage of establishments					
10 – 19	[illegible]	[illegible]	17	9	1	82
20 – 49	[illegible]	[illegible]	32	14	1	85
50 – 99	[illegible]	[illegible]	26	27	6	91
100 – 249	[illegible]	[illegible]	28	35	8	91
250 +	[illegible]	[illegible]	19	42	31	97
All	[illegible]	[illegible]	25	22	7	88

Table 9N: Number of Functional Areas in Which at Least One Advanced Technology is Used by Size of Establishment

Number of Functional Areas	Employment Size Group				
	10 - 19	20 - 49	50 - 99	100 - 249	250+
	percentage of establishments				
All areas	1	–	3	3	25
8 or more	2	1	12	16	44
7 or more	4	9	20	26	57
6 or more	10	17	31	43	71
5 or more	14	29	46	59	83
4 or more	29	43	57	69	90
3 or more	47	59	76	81	97
2 or more	66	71	85	86	97
1 or more	82	85	91	91	97

Table 90: Technology Use by Functional Area by Size Group

Functional area	Employment Size Group					
	10 - 19	20 - 49	50 - 99	100 - 249	250+	All
	percentage of establishments					
Processing	50	59	67	61	88	62
Process control	34	45	67	74	86	56
Quality control	27	40	44	57	72	44
Inventory and distribution	30	31	43	43	69	39
Management and information systems and communications	43	56	64	78	91	62
Materials preparation and handling	20	21	39	35	60	31
Pre-processing activities	20	33	36	47	61	36
Packaging	35	43	51	66	82	51
Design and engineering	7	7	21	30	66	20

- Over the size range 20 to 249 (that is, the three middle groups), the size or incidence-of-use relationship at the functional level is strong and increases monotonically for process control, quality control, management systems and communications, pre-processing, packaging, and design and engineering. However, this is not the case for processing, inventory and distribution, and materials preparation and handling (Table 90).

- The intensity of use of advanced technology increases across all size groups. The percentages of plants using 11 to 20 advanced technologies increase monotonically as the size of plant increases (Table 9M). Use of 21 or more technologies also increases with size, although not monotonically.

- The comprehensiveness of use also increases steadily across all size groups, although considerably less dramatically than between the smallest and largest plants. The percentages of plants that use advanced technologies in seven or more functional areas in the 20-to-49, 50-to-99, and 100-to-249 employee size groups are 9%, 20% and 26%, respectively (Table 9N).

In summary, there is a strong positive relationship between plant size and the use of advanced technologies in the food industry. This is evident with respect to the incidence, intensity and comprehensiveness of use. The higher incidence of use applies to all functional areas and sub-areas and most individual technologies. For six of the nine functional areas, the relationship of incidence to size is monotonic across the five size groups. There is little difference among size groups in the ranking of functional areas by incidence of use. The smallest absolute difference is in the processing area, and the largest is in design and engineering.

9.1.4 *Adoption rates by country of control*[17]

As we mentioned in the chapter on the food-processing industry, multinational firms play an important role in the global diffusion of advanced technologies, and they have a significant presence in the Canadian food industry. The advantages of multinational enterprises are typically related to their size, expertise and financial resources.

The results of this survey indicate that, in the food industry, foreign-controlled establishments are more likely to use advanced technologies than are Canadian-controlled plants:

- Ninety-six percent of foreign-controlled plants use at least one of the technologies identified in this study, compared with 87% of Canadian-controlled plants (Table 9P).

- Fifty-six percent of foreign-controlled plants use 11 or more advanced technologies, compared with 25% of the Canadian-controlled plants (Table 9P).

- Foreign-controlled plants are more likely to use advanced technologies in more than one functional area. In particular, 40% of the foreign-controlled plants use them in seven or more areas compared with 15% of the Canadian-controlled plants (Table 9Q).

[17] For the most part, the sample size for non-U.S. plants was too small to draw statistically significant distinctions between such plants and U.S.-controlled plants—although the former appeared to be slightly more advanced.

Table 9P: Number of Advanced Technologies Used by Country of Control

Country	Number of Technologies					
	None	1 - 5	6 - 10	11 - 20	21 +	At Least 1
	percentage of establishments					
Canada	13	36	26	20	5	87
Foreign	4	18	22	39	17	96
All	12	34	25	22	7	88

Table 9Q: Number of Functional Areas in Which at Least One Advanced Technology is Used by Country of Control

Number of areas	Canada	Foreign	All
	percentage of establishments		
All areas	3	11	4
8 or more	8	29	11
7 or more	15	40	18
6 or more	25	56	28
5 or more	36	68	40
4 or more	49	76	[illegible]
3 or more	65	88	67
2 or more	76	94	[illegible]
1 or more	87	96	88

- With one exception, foreign-controlled plants are significantly more likely to use advanced technologies in each of the functional areas (Table 9R). They are more than twice as likely to use them in advanced design and engineering, about twice as likely to use them in the areas of materials preparation and handling and pre-processing, and 50% more likely in other areas. The largest percentage-point differences are in process control, management and systems and communications, and pre-processing. The exception is processing where there is no difference. In the case of processing technologies, Canadian-controlled plants lead the way in non-thermal preservation methods, but lag in the sub-area of separation, concentration and water removal (Appendix Table A9.3).

Table 9R: Technology Use by Functional Area by Country of Control

Functional area	Canada	Foreign	All
	percentage of establishments		
Processing	62	62	62
Process control	52	86	56
Quality control	42	61	44
Inventory and distribution	38	45	39
Management and information systems and communications	59	91	62
Materials preparation and handling	29	50	31
Pre-processing activities	33	63	36
Packaging	49	68	51
Design and engineering	17	43	20

- Foreign-controlled plants are more than twice as likely to use advanced technologies in the process testing sub-area (See Appendix Table A9.2). This is also the case for automated statistical process control, programmable logic controllers, computerized process control, intercompany networks, and electronic detection of machinery failure. On the other hand, in addition to the processing area, Canadian-controlled plants are relatively advanced in the use of modified atmosphere packaging.

- For the most part, the sample size for non-U.S. plants was too small to draw distinctions between such plants and U.S.-controlled plants in the use of advanced technologies.

In summary, the overall incidence, intensity and comprehensiveness of use of advanced technologies is appreciably higher for foreign-controlled establishments than for Canadian-controlled establishments. The absolute difference is greatest for the functional areas of process control, management systems and communications and pre-processing and relatively greatest for design and engineering, and materials preparation and handling. The latter two, particularly design and engineering, have relatively low, overall usage rates. The greater use of management systems and communications technologies would be at least partly related to the greater challenge of effectively and efficiently monitoring and controlling the multi-plant operations of a multinational firm. There is no difference in the key area of processing technologies.

9.1.5 Adoption rates by stage of processing

As indicated above, while many technologies apply to a variety of food-processing plants, some technologies apply more to either primary or secondary processing. Also, as noted in the industry overview, 39% of food-industry plants specialize in primary processing, 22% specialize in secondary processing, and 39% do both (Table 4C).

There is not a large difference in the incidence of use by functional area among plants that differ by stage of processing. In all cases, the lowest rate is for primary processors; compared with secondary processors, the largest differences are in the areas of process control, packaging, communications, and design and engineering. In most cases, plants that do both primary and secondary processing have the highest adoption rates, but in all cases the margin is small. This general picture is not much different at the sub-functional level (see Appendix Table A9.4).

9.2 Factors Influencing Advanced Technology Adoption

9.2.1 Introduction

In preceding sections, we have used bivariate tables to show that the adoption of advanced technology varies by type of industry, size and country of control and the degree to which this is the case. In particular, large plants and foreign-controlled plants tend to be more technologically advanced. But these two characteristics are related, since foreign plants tend to be larger. However, bivariate analysis does not allow us to determine whether, for example, the influence of foreign direct investment on technology use is simply an artefact of the size of the plant or the industry in which it operates.

There are several questions that need to be answered. Does one industry use more advanced technologies because of differences in products produced or because it has more large plants? How large is the effect of plant size on technology use after other characteristics like batch processing are considered? Is technology intensity higher in the foreign sector because this sector operates larger plants, because of the industries in which they are active, or because of other production-related characteristics that distinguish foreign from domestic plants?

In this section, we use multivariate analysis to examine these issues by estimating the joint influence of size and nationality of ownership, as well as other plant and industry characteristics that have been hypothesized to affect technology adoption (see Chapter 4). This technique will determine whether nationality still matters after we have taken into account the other salient characteristics that are related to technology use. These plant characteristics include the type of production activity (stage of processing), production of volume products and continuous as opposed to batch operations. We have also hypothesized that the use of certain key business practices will be related to technology use, in part because they require certain advanced technologies to be effective.

9.2.2 The multivariate analysis

Firms adopt advanced technologies with the expectation of receiving an increase in profits. The expected post-adoption return from advanced technologies r_i^* for firm i is taken to be a function of a set of firm-specific and industry-specific exogenous variables x_i. This may be formally expressed as:

$$r_i^* = bx_i + u_i \quad \text{where u is a random variable}$$

Even though r_i^* is not directly observable, we can observe whether firm i adopted a new technology or not. We assume that when the expected return from technology adoption is positive, firms will adopt the new technology. The observable binary variable I_i takes a value of one when the firm is an advanced technology user and zero otherwise. Thus we can write:

$$I_i = 1 \quad \text{if } r_i^* > 0$$
$$I_i = 0 \quad \text{otherwise}$$

The expected return from technology adoption, given the characteristics of the firm and of the industry to which it belongs, is

$$E(r_i^* | x_i)$$

When this is greater than zero, $\text{Prob}(I_i=1)$, which in turn occurs when $\text{Prob}(u_i > -bx_i) = 1-F(-bx_i)$ where F is the cumulative density function for the residuals u_i. The choice of the statistical model to be used for multivariate analysis depends on assumptions about the form of the residuals u_i. If the cumulative distribution of residuals is normal, the probit model is the

appropriate choice; if it conforms to a logistic function, the logit model is appropriate. For practical purposes, the difference between the results of the two models is usually small. In this study, the logistic model will be used.

Technology adoption logistic regressions are estimated for each of the nine functional areas using the following model specification:

$$T_i = f(C_i, A_i)$$

where T_i refers to the incidence of technology use, C_i to a set of plant characteristics, and A_i to plant activities.

The plant characteristics, plant activities, and industry characteristics are hypothesized to be related to the benefits of using advanced technologies and are, therefore, included as proxies for the expected return r_i^*. These characteristics include plant size, ownership and the production capability of the firm. The latter is represented by the type of operation (batch versus continuous), the type of production activity (primary, secondary, or combined primary-secondary processing), and the extent to which the operation is a high-volume production unit. Like plant size and nationality, each of these are used to capture characteristics that are believed to affect the benefits that a plant can derive from the use of advanced technology. Plant size is included because larger plants are seen to derive greater benefits from advanced technology use—as the greater emphasis on technology strategies outlined in Chapter [illegible] confirms.

Nationality is included because of the advantage that foreign-owned plants are perceived to possess in transferring technologies across national boundaries (Cohen and Levin 1989). Plant activities are captured by business practices that are seen by some (Gordon and Wiseman 1995) to be closely related to the benefit that plants obtain from advanced technologies. Process innovation is also included because of its likely connection to the adoption of technologies. Binary industry variables are included to capture any industry-specific effects that are related to differences in technological opportunity.

9.2.3 Dependent variable

The dependent variable is a dichotomous variable capturing technology incidence measured at the functional technology level. It is a binary variable that takes a value of 1 if the plant is using at least one advanced technology from that functional group, and a value of 0 otherwise. For example, for processing technologies, the dependent variable takes a value of one if the establishment uses at least one of the processing technologies listed in the survey, and a value of zero otherwise.

9.2.4 Explanatory variables

Establishment size. Establishment size is measured by the number of production and non-production workers employed by the establishment. Five binary variables are constructed to capture size effects. They are based on the following five categories: 10 to 19 employees, 20 to 49 employees, 50 to 99 employees, 100 to 249 employees, and 250 or more employees.

Production type. Three binary variables control for differences in production activity. Plants are categorized in the survey as having only primary processing facilities, only secondary processing facilities, or facilities that engage in both primary and secondary processing activities. Accordingly, three binary variables are constructed. The first variable takes a value of one if the establishment is a pure primary processing plant, otherwise it is coded as zero if it is engaged in some secondary processing activity—either purely secondary or combined primary-secondary processing. Two other binary variables were defined in a similar fashion to represent plants that do only secondary processing, and those combining primary and secondary process activities, respectively.

Volume of products. This variable measures the percentage of shipments that managers categorize as high-volume products. It is a continuous variable ranging from 0% to 100%.

Batch versus continuous. To distinguish continuous from batch operations, we use a binary variable that takes a value of 1 if the plant is primarily a batch operation, and a value of 0 if it is primarily a continuous operation.

Ownership. Nationality is captured with a binary variable that takes a value of 1 if the establishment is foreign owned, and a value of 0 if the establishment is domestically owned.

Business practices. Establishments employ a variety of business practices and techniques aimed at improving their plant's operations. Three types of practices were investigated in the survey—practices aimed at enhancing the quality of products; practices

aimed at improving the handling and distribution of materials within and outside of the plant; and practices or techniques aimed at rapid product or process development.

Three variables are constructed capturing the number of practices an establishment uses from each of the three types of business practices.

Process innovation. Plants that introduce new process innovations are more likely to be using advanced technologies. Process innovation may, but does not necessarily, involve the list of technologies included here. To capture the relationship between innovation and technology use, a binary variable is included that takes on a variable of 1 when process innovation occurs and 0 otherwise.

Industry. Industry effects are also included. Seven binary variables are constructed for the seven sub-industries that are considered here—bakery, cereal, dairy, fish, fruit and vegetables, meat and other food products.

A summary of the dependent and explanatory variables for the sample used in the regression analysis is provided in Table 9S. For the binary variables, the proportion of establishments (a value that ranges from 0 to 1) exhibiting a certain characteristic is given, while for the continuous variables, the mean value of each is provided. For example, for the binary dependent variable QUALITY, 36% of the food-processing establishments use at least one advanced quality control technology. For the continuous variable VOLUME, we find that, on average, 63% of the shipments produced by plants are high-volume products.

9.2.5 Methodology

The actual form of the regression is:

$$\text{FUNCTECH} = \alpha_0 + \alpha_1{*}\text{SIZE} + \alpha_2{*}\text{FOREIGN} + \alpha_3{*}\text{PRODTYPE} + \alpha_4{*}\text{VOLUME} + \alpha_5{*}\text{BATCH} + \alpha_6{*}\text{PRACTICES} + \alpha_7{*}\text{INNOVPROC} + \alpha_8{*}\text{INDUSTRY}$$

where FUNCTECH measures the incidence of technology use at the functional technology level, and SIZE is the employment size of a firm. FOREIGN captures whether or not an establishment is foreign owned. PRODTYPE is a variable that indicates where on the value-added chain a plant falls—whether the production activity of the establishment involves primary processing, secondary processing, or both. VOLUME captures the extent to which the plant is engaged in high-volume production. BATCH is a variable that measures the extent to which the production takes place in a batch rather than a continuous operation. PRACTICES refers to the business practices used by establishments. INNOVPROC is a variable that indicates whether process innovation is occurring. INDUSTRY was included to capture industry effects.

Results of the logistic regressions for technology incidence in each of the functional areas are provided in Table 9T. All regressions are weighted and are estimated against an excluded plant that is small, engaged in primary processing, that does continuous processing, is Canadian owned, that is in the bakery industry, and has not introduced a process innovation in the last three years. Whereas the parameter estimates in Table 9T provide the qualitative effects of the explanatory variables, the probability estimates found in Table 9U provide the quantitative effects. The probabilities are calculated by estimating the logit function at the sample means.[18]

9.2.6 Empirical results

Employment size (ESTSIZE) is an important determinant of technology use across all functional groups. The coefficient on the largest size class is statistically significant across all functional groups, that is, large plants are more likely to adopt at least one technology from a functional group than are smaller plants. For most of the functional areas, the probability of adopting an advanced technology from a functional group increases monotonically with size of plant. This size advantage is greatest for communications, process control, packaging and design technologies (Table 9U). There is a 46 percentage-point difference in the probability of adopting advanced communication technologies between the largest and the smallest plants. Large differences are also found for process control technologies (39 percentage points) and design and engineering technologies (33 percentage points).

The coefficient for nationality of ownership (FOREIGN) is positive, for all but processing and inventory and distribution technologies, and is highly significant for about half of the functional groups. This means that foreign-owned establishments are significantly more likely to adopt technology than are domestically

[18] Probabilities (p) are estimated using the logit equation: $P = \exp(\beta x)/[1 + \exp(\beta x)]$

Table 9S: Summary Statistics for Dependent and Independent Variables for Technology Adoption Logistic Regression

Variable	Description	Mean	Standard deviation
1. Dependent variable			
Incidence of use	Incidence of Functional Technology Use		
PROCESS	– processing	0.61	0.48
PROCCNTL	– process control	0.57	0.50
QUALITY	– quality control	0.36	0.49
DISTRIB	– inventory and distribution	0.39	0.49
COMMUNIC	– management systems and communications	0.64	0.48
MATERIAL	– materials preparation and handling	0.31	0.46
PREPROC	– pre-processing	0.36	0.48
PACKAGE	– packaging	0.52	0.50
DESIGN	– design and engineering	0.20	0.40
2. Plant characteristics			
Establishment Size	Employment size		
ESTSIZE1	– 10 to 19 employees	0.23	0.42
ESTSIZE2	– 20 to 49 employees	0.28	0.45
ESTSIZE3	– 50 to 99 employees	0.20	0.40
ESTSIZE4	– 100 to 249 employees	0.18	0.39
ESTSIZE5	– 250 or more employees	0.10	0.30
Ownership	Country of Control		
FOREIGN	– Foreign owned	0.11	0.32
Production Type	Stage of Processing		
PRODTYP1	– primary processing	0.39	0.49
PRODTYP2	– secondary processing	0.22	0.42
PRODTYP3	– both primary and secondary	0.38	0.49
Volume of Products	High Volume Production		
VOLUME	– percentage of products that are high volume	62.5	30.1
Type of Operation	Type of Operation		
BATCH	– batch (as opposed to continuous) operations	0.48	0.50
3. Plant activities			
Business Practices	Incidence of Business Practices Use		
PRACT_A	– product quality practices	4.82	2.17
PRACT_B	– management practices	2.44	2.22
PRACT_C	– product/process development practices	2.27	2.36
Innovation	Incidence of Process Innovation		
PROCINNOV	– percentage of establishments with process innovation	0.37	0.48
4. Industry characteristics			
IND_BAKE	Bakery industry	0.15	0.36
IND_CERE	Cereal industry	0.15	0.35
IND_DAIR	Dairy industry	0.10	0.30
IND_FISH	Fish products industry	0.15	0.36
IND_VEGG	Fruit and vegetables industry	0.07	0.26
IND_MEAT	Meat industry	0.19	0.39
IND_OTHR	Other food products industry	0.19	0.40

Note: All means are weighted population estimates

owned ones, even after size and other plant characteristics are taken into account. The largest significant nationality effects occur for process control, communications and pre-processing. Being foreign-owned adds 24 percentage points to the probability of adopting advanced process control and advanced communication technologies. For pre-processing, the advantage is 18 percentage points. Overall, these results confirm our hypothesis that foreign owned establishments are the most likely to be technology users and demonstrates where this occurs—in the areas outside the central processing area.

Production type (PRODTYPE) is generally positive. The coefficient is significant for design and engineering and automated materials handling technologies. Even though the coefficient is significant for design and engineering, the effect on the probability of successful adoption is small. Establishments engaged in some type of secondary processing activity have an eight percentage point advantage when it comes to adopting automated materials handling technologies.

The use of business practices is found to be positively and significantly associated with the adoption of advanced technology. Business practices (PRACT_A) aimed at enhancing product quality are positively and significantly related to technology use. Establishments using practices such as continuous quality improvement and hazard analysis critical control points (HACCP) are more likely to adopt all types of advanced technology. For all but packaging technology, this relationship is highly significant. The impact is greatest for processing, process control and quality control technologies. Therefore, quality practices influence the adoption of more than just the technologies that we have grouped under the rubric "quality-control technologies". They also influence the adoption of technologies in processing, pre-processing, and communications.

Business practices aimed at materials and distribution management (PRACT_B), such as just-in-time inventory control and materials requirement planning are also positively related to technology use across all functional groups. They are highly statistically significant for communications technologies. The third set of practices dealing with product and process development (PRACT_C) have positive coefficients that are statistically significant for all but communications.

Innovation activities are also important determinants of advanced technology use. Plants that indicated that they had recently introduced a process innovation were more likely to use advanced technologies from each of the functional groups. Only for inventory and distribution and design and engineering are these results not statistically significant. Nevertheless, it is significant that process innovation is not a sufficient condition for the use of advanced technologies. Plants that do not report process innovations have a relatively high probability of reporting advanced technology use and those reporting process innovations do not all use advanced technologies (Table 9U). While process innovation involves more than just advanced technologies, the advanced technologies investigated here are an important part of many process innovations.

Establishments that are high-volume producers are the most likely to adopt advanced technology. This result is statistically significant for process control, automated material handling, design, pre-processing and quality control technologies.

On the other hand, if an establishment is primarily a batch operation, there is less likelihood that it will use advanced technologies in the areas of design, distribution, materials handling, processing, quality control and pre-processing technologies. The latter two are highly significant. The biggest effect is found for pre-processing for which there is an 11 percentage point difference in the probability of adoption. Most of these are also areas where volume has a significantly positive effect on the adoption of advanced technologies. However, plants that concentrate on batch operations are significantly more likely to adopt communications technologies; this is not an area where volume has much of an impact.[19]

The industry to which an establishment belongs influences the likelihood that it will adopt advanced technology. Establishments in the dairy industry are the most likely to adopt at least one technology from each of six functional groups: processing, process control, quality control, communications, pre-processing and packaging. Establishments in the fish products and bakery industries are generally among the least likely to adopt a technology from most functional groups—processing, quality control, pre-processing, packaging, and design for bakery; and process control, quality control, inventory, communications, packaging and design for fish products. Cereal establishments have a higher probability of adoption than most for materials, process control, pre-processing, and design. Establishments in the fruit and vegetable industries and "other" food products industry tend to reflect the industry average, with the exception of quality control and packaging where it is among the leaders. Plants in the meat industry are more likely than plants in most other industries to adopt processing, quality control, inventory and packaging technologies.

We also estimated regressions for the intensity of adoption but do not report them here. Most of the earlier results hold. Similar to the results found for the technology incidence regression, size matters. While the coefficient attached to foreign ownership is positive, it is statistically significant only for process control, quality control and pre-processing technologies. It is negative and statistically significant for process and distribution technologies. Production type is slightly more important here than for the incidence regression. Unlike the incidence regression, production type was found not to matter for design

[19] The exclusion of either the volume or the batch variable from the equation does not affect the significance of the other variable.

technologies but was found to matter for packaging and process control technologies. Establishments that are engaged in secondary processing, either solely or in combination with primary processing activities, tend to adopt greater numbers of packaging and process control technologies. Business practices were found to have the same effect for both regressions. Product volume has much less of an effect than for the incidence regression. Only for process control and automated material handling is the estimated coefficient positive and significant. Whether a plant is primarily a batch operation is rarely significant. Only for quality control and pre-processing is it important, with continuous operations being more likely to use greater numbers of these types of technologies. Results similar to the technology incidence regression are found for the industry variables. Plants in the dairy, cereal and meat industries are generally ahead (although cereal plants lag significantly when it comes to process and packaging technology); plants in the fish and bakery industries are generally behind; and plants in the fruit and vegetable and "other" products industries tend to reflect the industry average.

Table 9T: Logistic Regression Results for Intensity of Technology Adoption by Functional Technology Group

Variable	Processing	Process control	Quality control	Inventory and distribution	Management systems and communi-cations	Materials prepara-tion and handling	Pre-processing	Packaging	Design and engineering
INTERCEPT	-1.623***	-3.390***	-4.264***	-1.784***	-1.987***	-2.978***	-4.440***	-2.186***	-5.734***
Plant Characteristics									
Establishment Size									
ESTSIZE2	0.007	0.228	-0.009	0.038	0.517**	-0.222	0.356	0.201	0.022
ESTSIZE3	0.070	1.159***	0.403	0.565**	0.764***	0.629**	0.394	0.328	1.194***
ESTSIZE4	-0.338	1.555***	0.694**	0.481*	1.734***	0.236	0.672**	0.894***	1.695***
ESTSIZE5	0.715*	1.694***	0.896**	1.251***	2.482***	0.976***	0.696*	1.236***	2.636***
Ownership									
FOREIGN	-0.497*	1.054***	0.346	-0.252	1.311***	0.310	0.829***	0.140	0.610**
Production Type									
PRODTYP2	0.119	0.261	0.063	0.156	0.343	0.195	0.091	0.257	0.670**
PRODTYP3	0.208	0.025	0.149	0.106	0.226	0.356*	0.086	0.280	0.505*
Volume of Products									
VOLUME	0.003	0.013***	0.007**	-0.001	0.001	0.009***	0.006*	0.004	0.008*
Type of Operation									
BATCH	-0.033	0.069	-0.337*	-0.176	0.381**	-0.255	-0.570***	0.065	-0.153
Plant Activities									
Business Practices									
PRACT_A	0.244***	0.227***	0.269***	0.098**	0.189***	0.175***	0.211***	0.070	0.146**
PRACT_B	0.010	0.107*	0.048	0.089*	0.201***	0.029	0.001	0.061	0.062
PRACT_C	0.097*	0.120*	0.135***	0.081*	-0.020	0.078*	0.147***	0.223***	0.148***
Process Innovator									
INNOVPROC	0.519***	0.625***	0.327*	0.001	0.554**	0.738***	0.570***	0.313*	0.353
Industry Characteristics									
IND_CERE	-0.327	0.674**	0.993***	-0.145	0.460	0.679**	2.027***	-0.317	1.742***
IND_DAIR	0.970***	1.169***	2.214***	-0.212	-0.138	-0.519	2.191***	0.981***	0.501
IND_FISH	0.591*	-0.993***	0.534	-0.369	-1.127***	-0.477	1.302***	-0.142	0.316
IND_VEGG	0.719**	0.443	0.872**	0.103	-0.248	-0.286	1.460***	0.502	0.813*
IND_MEAT	0.638**	0.333	1.223***	0.794***	-0.329	-0.621*	1.755***	0.712**	0.766*
IND_OTHR	0.043	0.207	[illegible]	0.495	0.350	-0.386	1.528***	0.703**	0.888**
Summary Statistics									
N	794	794	794	794	794	794	794	794	794
χ^2	109.7	158.8	165.9	94.2	153.8	134.6	180.6	138.6	162.8
Log Likelihood	-458	-390	-403	-472	-395	-413	-411	-451	-282

Note: *** significant at the 1% level; ** significant at the 5% level; * significant at the 10% level

Table 9U: Estimated Probability of Adopting Specific Functional Technologies

Variable	Processing	Process control	Quality control	Inventory and distribution	Management systems and communi-cations	Materials prepara-tion and handling	Pre-processing	Packaging	Design and engineering
Plant Characteristics									
Establishment Size									
ESTSIZE1	57	37	20	32	45	27	22	23	4
ESTSIZE2	57	37	20	32	58	27	22	23	4
ESTSIZE3	57	65	20	45	63	41	22	23	12
ESTSIZE4	57	74	34	43	82	27	36	43	19
ESTSIZE5	73	76	39	62	91	50	37	51	37
Ownership									
FOREIGN	47	75	24	39	86	32	42	29	14
NON-FOREIGN	60	51	24	39	62	32	24	29	8
Production Type									
PRODTYP1	58	54	24	39	66	29	26	29	6
PRODTYP2	58	54	24	39	66	29	26	29	12
PRODTYP3	58	54	24	39	66	37	26	29	10
Volume of Products									
VOLUME	58	54	24	39	66	32	26	29	9
MEAN+SD	58	63	28	39	66	38	30	29	11
MEAN-SD	58	44	21	39	66	26	23	29	7
Type of Operation									
BATCH	58	54	21	39	70	32	21	29	9
NO BATCH	58	54	27	39	62	32	32	29	9
Plant Activities									
Business Practices									
PRACT_A	58	54	24	39	66	32	26	29	9
MEAN+SD	70	66	36	44	74	40	36	29	12
MEAN-SD	45	42	15	34	56	24	18	29	7
PRACT_B	58	54	24	39	66	32	26	29	9
MEAN+SD	58	60	24	44	75	32	26	29	9
MEAN-SD	58	48	24	35	55	32	26	29	9
PRACT_C	58	54	24	39	66	32	26	29	9
MEAN+SD	64	61	31	44	66	36	33	41	12
MEAN-SD	53	47	19	35	66	28	20	19	6
Process Innovator									
INNOVPROC	66	64	28	39	73	43	33	33	9
NON-INNOVPROC	54	48	22	39	61	26	22	27	9
Industry Characteristics									
IND_BAKE	49	52	11	36	69	32	8	22	5
IND_CERE	49	68	26	36	69	48	39	22	23
IND_DAIR	72	78	54	36	69	32	43	43	5
IND_FISH	64	29	11	36	42	32	23	22	5
IND_VEGG	67	52	24	36	69	32	26	22	10
IND_MEAT	65	52	30	55	69	20	32	36	10
IND_OTHR	49	52	32	36	69	32	28	36	11

9.3 Summary and Conclusions

While a large proportion of food-processing establishments use at least one advanced technology, the incidence and intensity of use differs appreciably by industry, plant size and country of control.

These results are evident from the simple bivariate tables produced in section 9.1. The results of multivariate analysis show that a number of other characteristics are related to technology use. Plants engaged in some type of secondary processing, either alone or in conjunction with primary processing, are a little more likely to use advanced technologies. Plants with high-volume and continuous operations are more likely to use advanced technologies. The use of business practices is also positively associated with technology use, particularly quality practices.

The statistical analysis also shows that after the effects of production characteristics are accounted for, larger plants are more likely to use advanced

technologies. This result also applies to foreign-controlled plants compared with Canadian-controlled plants.

At the industry level, the leading users of advanced technologies are clearly the dairy, "other" and fruit and vegetable industries when plant characteristics are not taken into account. When differences in size, control and the other variables analysed are considered, some changes occur in the relative ranking of different industries. Dairy plants are still the most likely to adopt advanced technology, while the fruit and vegetable and "other" industries no longer differ much from the average. The cereal industry, however, becomes one of the more important users. The fish and bakery industries are still among the least likely to use many advanced technologies.

Appendix – Chapter 9

Table A9.1: Incidence of Individual Advanced Technology Use by Industry

Technology	Bakery	Cereal	Dairy	Fish	Fruit and Vegetables	Meat	Other	All
				percentage of establishments				
1. PROCESSING	50	44	77	70	73	67	61	62
1.1 Thermal preservation	17	11	41	21	41	31	29	26
a) aseptic processing	7	1	35	11	30	18	12	14
b) retortable flexible packages	6	–	10	8	13	12	13	9
c) infra-red heating	1	3	8	1	3	1	3	3
d) ohmic heating	–	1	–	1	3	1	–	1
e) microwave heating	6	1	5	3	4	3	6	4
f) other	4	4	6	4	7	6	5	5
1.2 Non-thermal preservation	32	16	34	65	54	52	26	39
a) chemical antimicrobials	8	9	19	13	32	21	17	16
b) ultrasonic techniques	1	–	–	–	–	4	4	2
c) high pressure sterilization	2	8	15	16	13	10	4	9
d) deep chilling	27	1	19	51	24	40	11	25
e) other	1	–	1	8	8	2	2	3
1.3 Separation, concentration and water removal	12	19	49	31	38	35	35	30
a) membrane process	–	1	21	5	13	3	5	5
b) filter technologies	4	7	23	12	22	17	21	15
c) centrifugation	–	2	40	8	12	6	13	10
d) ion exchange	–	1	6	1	8	1	4	3
e) vacuum microwave drying	–	–	–	5	1	2	–	1
f) water activity control	10	12	14	23	20	21	14	16
g) other	–	2	1	2	–	2	1	1
1.4 Additives or ingredients	17	28	50	9	11	17	14	19
a) bio-ingredients	15	28	33	6	10	9	8	14
b) microbial cells	4	6	29	2	3	9	6	8
c) other	–	1	4	4	–	2	3	2
1.5 Other	–	1	6	2	2	3	2	2
a) electrotechnologies	–	1	5	2	2	2	–	1
b) microencapsulation	–	–	1	–	–	1	2	1
c) other	–	–	1	1	–	1	–	1
2. PROCESS CONTROL	46	58	77	40	67	54	63	56
a) automated sensor-based equipment for inspection/testing	17	19	31	16	31	19	28	22
b) automated statistical process control	11	12	21	12	19	12	13	14
c) machine vision	6	10	10	9	27	5	8	9
d) bar coding	11	9	23	17	25	30	18	19
e) programmable logic controllers	29	37	62	12	49	29	49	36
f) computerized process control	22	46	56	19	35	24	31	32
g) other	2	2	1	1	2	3	1	2
3. QUALITY CONTROL	22	41	69	46	44	44	52	44
3.1 Process testing	14	20	63	18	32	31	37	29
a) chromatography	2	6	9	–	6	4	12	6
b) monoclonal antibodies	–	1	9	2	6	4	3	3
c) DNA probes	1	1	2	1	2	1	–	1
d) rapid testing techniques	10	18	56	14	26	26	30	24
e) other	3	–	2	3	3	3	5	3

Table A9.1: Incidence of Individual Advanced Technology Use by Industry – *(Continued)*

Technology	Bakery	Cereal	Dairy	Fish	Fruit and Vegetables	Meat	Other	All
				percentage of establishments				
3.2 Laboratory testing	11	29	34	26	21	25	28	25
a) automated	4	14	25	8	10	14	18	13
b) other	7	18	10	20	14	15	13	14
3.3 Simulation	6	7	9	12	12	5	5	7
a) mathematical modelling of quality or safety	5	6	8	11	12	5	5	7
b) other	1	1	1	1	–	–	–	1
4. INVENTORY AND DISTRIBUTION	31	28	36	32	39	52	49	39
a) bar coding	28	16	32	28	35	48	43	34
b) automated product handling	6	15	11	7	17	10	12	11
c) other	–	1	3	3	2	2	3	2
5. MANAGEMENT AND INFORMATION SYSTEMS AND COMMUNICATIONS	54	71	67	50	64	55	75	62
a) local area network	36	51	45	27	51	38	55	43
b) wide area network	19	20	30	11	23	15	29	20
c) inter-company computer networks	30	44	49	28	38	36	40	37
d) Internet— marketing and promotion	19	29	23	29	26	27	35	27
e) Internet—other	13	31	25	30	23	19	42	27
f) other	1	4	–	1	3	2	1	1
6. MATERIALS PREPARATION AND HANDLING	27	43	33	26	34	26	31	31
a) integrated electronically controlled machinery	13	12	8	8	8	9	11	10
b) individual electronically controlled non-integrated machinery	8	10	14	10	11	10	11	10
c) electronic detection of machinery failure	16	39	26	20	27	18	21	23
d) other	–	–	1	–	1	1	–	–
7. PRE-PROCESSING ACTIVITIES	13	42	55	36	39	38	38	36
7.1 Raw product quality enhancement	3	13	3	5	–	14	3	6
a) animal stress reduction	–	–	–	2	–	14	1	3
b) bran removal before milling	2	8	–	–	–	–	2	2
c) micro component separation	1	3	3	–	–	–	1	1
d) other	1	2	–	3	–	–	–	1
7.2 Raw product quality assessment	12	37	54	34	39	32	38	34
a) electronic or ultrasonic grading	1	4	5	6	7	6	1	4
b) collagen, colour or PSE probe	1	2	–	6	2	6	4	3
c) near infra-red analysis	1	19	30	1	1	4	10	9
d) colour assessment or sorting	6	19	10	20	30	17	20	17
e) electromechanical defect sorting	1	3	4	4	12	3	5	4
f) rapid testing techniques	5	16	50	9	18	25	21	19
g) other	3	4	4	5	1	1	1	3
8. PACKAGING	38	32	67	43	59	56	65	51
8.1 Equipment	27	23	49	29	50	29	47	35
a) non-integrated electronically controlled packaging machinery	23	20	43	26	38	26	36	29
b) integrated electronically controlled packaging machinery	11	11	21	9	27	10	24	15
8.2 Preservation	11	2	29	14	18	39	15	18
a) modified atmosphere	11	2	29	14	18	39	15	18

Table A9.1: Incidence of Individual Advanced Technology Use by Industry – *(Concluded)*

Technology	Bakery	Cereal	Dairy	Fish	Fruit and Vegetables	Meat	Other	All
	percentage of establishments							
8.3 Advanced materials	[illegible]	[illegible]	44	25	28	35	49	32
a) laminates	7	[illegible]	30	12	17	24	28	18
b) active packaging	5	[illegible]	4	10	8	3	7	5
c) multi-layer	[illegible]	[illegible]	36	12	22	26	32	22
8.4 Other	–	–	[illegible]	–	–	–	–	–
9. DESIGN AND ENGINEERING	[illegible]	[illegible]	[illegible]	15	26	22	23	20
a) CAD and/or CAE	[illegible]	[illegible]	[illegible]	15	24	19	20	18
b) CAD/CAM	[illegible]	[illegible]	4	4	7	5	6	5
c) computer aided simulation and prototypes	[illegible]	[illegible]	[illegible]	2	4	1	7	3
d) digital representation of CAD output used in procurement	–	[illegible]	[illegible]	1	–	1	3	2
e) other	[illegible]	[illegible]	[illegible]	–	–	1	–	1

Table A9.2: Incidence of Individual Advan[illegible] by Size Group

Technology	Employment Size Group 50 - 99	100 - 249	250+	All
	percentage of establishments			
1. PROCESSING	67	61	88	62
1.1 Thermal preservation	27	25	48	26
a) aseptic processing	16	15	37	14
b) retortable flexible packages	8	12	11	9
c) infra-red heating	2	4	6	3
d) ohmic heating	1	1	–	1
e) microwave heating	4	3	9	4
f) other	5	1	12	5
1.2 Non-thermal preservation	39	43	65	39
a) chemical antimicrobials	15	17	31	16
b) ultrasonic techniques	2	3	5	2
c) high pressure sterilization	11	9	11	9
d) deep chilling	26	28	46	25
e) other	2	7	4	3
1.3 Separation, concentration and water removal	35	30	50	30
a) membrane process	8	5	14	5
b) filter technologies	15	16	32	15
c) centrifugation	13	10	24	10
d) ion exchange	3	3	7	3
e) vacuum microwave drying	–	3	4	1
f) water activity control	18	15	28	16
g) other	1	2	–	1
1.4 Additives or ingredients	22	15	32	19
a) bio-ingredients	14	12	24	14
b) microbial cells	10	7	12	8
c) other	3	1	2	2
1.5 Other	1	1	6	2
a) electrotechnologies	1	1	5	1
b) microencapsulation	–	–	1	1
c) other	–	–	2	1
2. PROCESS CONTROL	67	74	86	56
a) automated sensor-based equipment for inspection/testing	27	38	37	22

Table A9.2 : Incidence of Individual Advanced Technology Use by Size Group – *(Continued)*

Functional area	Employment Size Group					
	10 - 19	20 - 49	50 - 99	100 - 249	250+	All
	percentage of establishments					
b) automated statistical process control	4	6	16	21	38	14
c) machine vision	6	7	10	12	16	9
d) bar coding	7	14	16	26	49	19
e) programmable logic controllers	16	24	49	48	70	36
f) computerized process control	13	24	37	47	60	32
g) other	1	3	2	2	4	2
3. QUALITY CONTROL	27	40	44	57	72	44
3.1 Process testing	13	22	34	39	55	29
a) chromatography	3	3	5	8	13	6
b) monoclonal antibodies	1	2	3	1	14	3
c) DNA probes	1	–	1	2	3	1
d) rapid testing techniques	10	18	31	33	45	24
e) other	1	6	3	3	1	3
3.2 Laboratory testing	19	23	22	34	30	25
a) automated	10	8	14	18	19	13
b) other	11	17	10	19	12	14
3.3 Simulation	4	6	7	12	11	7
a) math modelling of quality or safety	4	5	6	11	11	7
b) other	–	1	1	1	–	1
4. INVENTORY AND DISTRIBUTION	30	31	43	43	69	39
a) bar coding	25	27	35	37	66	34
b) automated product handling	6	7	13	13	24	11
c) other	2	2	2	1	1	2
5. MANAGEMENT AND INFORMATION SYSTEMS AND COMMUNICATIONS	43	56	64	78	91	62
a) local area network	24	38	46	53	75	43
b) wide area network	7	12	18	30	61	20
c) inter-company computer networks	18	27	42	52	74	37
d) Internet—marketing and promotion	15	23	25	40	48	27
e) Internet—other	18	25	26	35	39	27
f) other	2	–	3	2	3	1
6. MATERIALS PREPARATION AND HANDLING	20	21	39	35	60	31
a) integrated electronically controlled machinery	3	8	16	15	15	10
b) individual electronically controlled non-integrated machinery	8	6	9	13	27	10
c) electronic detection of machinery failure	13	15	28	29	46	23
d) other	–	1	–	–	1	–
7. PRE-PROCESSING ACTIVITIES	20	33	36	47	61	36
7.1 Raw product quality enhancement	5	6	6	7	12	6
a) animal stress reduction	3	2	3	2	9	3
b) bran removal before milling	1	1	1	3	3	2
c) micro component separation	–	1	1	2	3	1
d) other	1	2	–	1	–	1
7.2 Raw product quality assessment	18	29	35	44	59	34
a) electronic or ultrasonic grading	2	2	3	6	11	4
b) collagen, colour or PSE probe	–	2	5	4	9	3
c) near infra-red analysis	5	4	10	10	24	9

Table A9.2 : Incidence of Individual Advanced Technology Use by Size Group – (Concluded)

Functional area	10 - 19	20 - 49	50 - 99	100 - 249	250+	All
	Employment Size Group					
	percentage of establishments					
d) colour assessment or sorting	9	13	18	22	33	17
e) electromechanical defect sorting	–	2	2	7	15	4
f) rapid testing techniques	8	15	22	24	44	19
g) other	1	3	2	4	3	3
8. PACKAGING	35	43	51	66	82	51
8.1 Equipment	21	25	37	48	65	35
a) non-integrated electronically controlled packaging machinery	15	21	32	40	58	29
b) integrated electronically controlled packaging machinery	9	6	16	22	39	15
8.2 Preservation	11	17	18	22	34	18
a) modified atmosphere	11	17	18	22	34	18
8.3 Advanced materials	23	22	33	41	57	32
a) laminates	12	12	16	24	43	18
b) active packaging	5	3	6	9	5	5
c) multi-layer	12	16	24	30	48	22
8.4 Other	–	–	–	–	–	–
9. DESIGN AND ENGINEERING	7	7	21	30	66	20
a) CAD and/or CAE	6	6	18	27	60	18
b) CAD or CAM	2	3	2	11	14	5
c) computer aided simulation and prototypes	2	1	2	6	9	3
d) digital representation of CAD output	1	–	1	2	9	2
e) other	1	–	1	–	3	1

Table A9.3: Incidence of Individual Advanced Technology Use by Country of Control

Technology	Canada	Foreign	All
	percentage of establishments		
1. PROCESSING	62	62	62
1.1 Thermal preservation	25	27	26
a) aseptic processing	14	14	14
b) retortable flexible packages	9	4	9
c) infra-red heating	3	3	3
d) ohmic heating	1	2	1
e) microwave heating	4	5	4
f) other	5	6	5
1.2 Non-thermal preservation	40	29	39
a) chemical antimicrobials	16	17	16
b) ultrasonic techniques	1	4	2
c) high pressure sterilization	10	3	9
d) deep chilling	27	11	25
e) other	3	4	3
1.3 Separation, concentration and water removal	29	37	30
a) membrane process	5	6	5
b) filter technologies	14	22	15
c) centrifugation	10	12	10
d) ion exchange	2	7	3

Table A9.3: Incidence of Individual Advanced Technology Use by Country of Control – *(Continued)*

Technology	Canada	Foreign	All
		percentage of establishments	
e) vacuum microwave drying	1	–	1
f) water activity control	16	20	16
g) other	1	2	1
1.4 Additives or ingredients	19	19	19
a) bio-ingredients	14	15	14
b) microbial cells	8	4	8
c) other	2	2	2
1.5 Other	2	1	2
a) electrotechnologies	2	–	1
b) microencapsulation	–	1	1
c) other	–	1	1
2. PROCESS CONTROL	52	86	56
a) automated sensor-based equipment for inspection/testing	21	33	22
b) automated statistical process control	11	33	14
c) machine vision	9	13	9
d) bar coding	18	22	19
e) programmable logic controllers	31	77	36
f) computerized process control	28	60	32
g) other	2	–	2
3. QUALITY CONTROL	42	61	44
3.1 Process testing	26	55	29
a) chromatography	4	18	6
b) monoclonal antibodies	3	5	3
c) DNA probes	1	2	1
d) rapid testing techniques	22	44	24
e) other	3	6	3
3.2 Laboratory testing	24	29	25
a) automated	12	20	13
b) other	14	12	14
3.3 Simulation	7	8	7
a) mathematical modelling of quality or safety	7	7	7
b) other	–	1	1
4. INVENTORY AND DISTRIBUTION	38	45	39
a) bar coding	34	34	34
b) automated product handling	10	16	11
c) other	2	3	2
5. MANAGEMENT AND INFORMATION SYSTEMS AND COMMUNICATIONS	59	91	62
a) local area network	39	71	43
b) wide area network	17	44	20
c) inter-company computer networks	33	70	37
d) Internet—marketing and promotion	27	29	27
e) Internet—other	26	34	27
f) other	1	7	1
6. MATERIALS PREPARATION AND HANDLING	29	50	31
a) integrated electronically controlled packaging machinery	10	12	10
b) individual electronically controlled non-integrated machinery	9	19	10
c) electronic detection of failure	20	43	23
d) other	–	1	–

Table A9.3: Incidence of Individual Advanced Technology Use by Country of Control – *(Continued)*

Technology	Canada	Foreign	All
		percentage of establishments	
7. PRE-PROCESSING ACTIVITIES	33	63	36
7.1 Raw product quality enhancement	6	9	6
a) animal stress reduction	3	3	3
b) bran removal before milling	1	5	2
c) micro component separation	1	2	1
d) other	1	–	1
7.2 Raw product quality assessment	30	61	34
a) electronic or ultrasonic grading	4	3	4
b) collagen, colour or PSE probe	3	2	3
c) near infra-red analysis	5	34	9
d) colour assessment or sorting	15	29	17
e) electromechanical defect sorting	3	11	4
f) rapid-testing techniques	17	34	19
g) other	2	3	3
8. PACKAGING	49	68	51
8.1 Equipment	32	57	35
a) non-integrated electronically controlled packaging machiney	27	46	29
b) integrated electronically controlled packaging machinery	13	30	15
8.2 Preservation	19	14	18
a) modified atmosphere	19	14	18
8.3 Advanced materials	30	49	32
a) laminates	17	25	18
b) active packaging	5	5	5
c) multi-layer	20	42	22
8.4 Other	–	–	–
9. DESIGN AND ENGINEERING	17	43	20
a) CAD and/or CAE	15	39	18
b) CAD or CAM	5	5	5
c) computer-aided simulation and prototypes	3	6	3
d) digital representation of CAD output	1	4	2
e) other	[illegible]	–	1

Table A9.4: Incidence of Advanced Technology Use by Stage of Processing

Technology	Type of processing			
	Primary and secondary	Primary only	Secondary only	All
	percentage of establishments			
PROCESSING	65	55	59	62
Thermal preservation	28	16	21	26
Non-thermal preservation	42	34	37	39
Separation, concentration and water removal	34	29	22	30
Additives or ingredients	19	16	20	19
Other	3	2	1	2
PROCESS CONTROL	59	49	60	56
QUALITY CONTROL	41	31	33	44
Process testing	31	24	27	29
Laboratory testing	16	12	9	25
Simulation	7	6	8	7
INVENTORY AND DISTRIBUTION	43	32	40	39
MANAGEMENT AND INFORMATION SYSTEMS AND COMMUNICATIONS	67	54	69	62
MATERIALS PREPARATION AND HANDLING	37	24	31	31
PRE-PROCESSING ACTIVITIES	40	30	33	36
Enhancement	9	5	1	6
Assessment	37	28	33	34
PACKAGING	58	42	54	51
Equipment	42	26	38	35
Preservation	20	18	16	18
Advanced materials	40	20	37	32
DESIGN AND ENGINEERING	26	12	22	20

Chapter 10 – Effects of Advanced Technology Adoption

The previous chapter has outlined the areas in which advanced technologies have found their greatest use. This chapter focuses on where they have their greatest economic impact. In addition, it compares the relative rankings derived from the economic impact of different technologies to the relative rankings derived from their intensity of use. Finding that patterns of use broadly conform to economic impact would confirm that usage responds to existing economic incentives. If it has not done so, we have evidence of a possible disequilibrium, where use does not correspond to perceived benefits. The chapter also examines the extent to which economic impact varies across firm types (by size and by nationality of control). Since technology use is often less in smaller plants, it is important to know whether smaller plants find the new technologies to be less effective.

The economic benefits of technology use range from quality enhancement to cost reduction. The ultimate decision to adopt new technologies probably does not rest on one specific effect but on the combined effect of a number of influences. Therefore, we focus here on both the general impact as well as the specific effects of technology use. The chapter also links effects to plant characteristics and technology use through multivariate analysis. By doing so, we identify which technologies are having the greatest economic impact.

10.1 Technology, Productivity and Economic Growth

Technology use is seen to be associated with greater productivity growth and greater competitiveness. Traditional economic growth models consider the roles of research and development, innovation and growth in a more or less linear, cause–effect relationship. Newer models focus more on the interactions among them (McFetridge 1995; Gibbons 1995; Fortin and Helpman 1995).[20] The relationship between technology use and productivity growth has been demonstrated for the manufacturing sector by Baldwin, Diverty and Sabourin (1995).

New products and services such as computers, microwave ovens and fresher tasting processed foods are obvious examples of the contribution made by new technologies to economic welfare. Productivity gains are apparent in reduced costs and changed employment patterns. As indicated, output per worker has increased in the food-processing sector by about 1% per year since 1980. Changes in output per worker are caused by increases in capital per worker, better management practices, and improvements in technology. The latter are subsumed in multifactor productivity measures.

The contribution of technological change to productivity growth is difficult to assess using aggregate data. Labour productivity is a function of the capital stock and other variables, as well as technology. While crude measures of capital stock are available and can be incorporated into multifactor productivity measures, they do not allow for nuances in the type of technology that is embedded in the capital stock.

Technological change can be measured at the industry level when data are available on the amount invested in a specific new technology. For example, an econometric analysis of capital investment and productivity in the U.S. food and kindred products industry (U.S. SIC 20) used investment in office and information technology equipment to represent advanced technology use and found that the increased use of high technology capital (as measured by this variable) reduced costs, stimulated investment in other equipment and structures, and reinforced the positive effect of disembodied technical change on productivity (Morrison 1997).

This study found that an increase in high technology relative to other capital components led to larger capital and energy shares, less labour and no change in material inputs—effects that appeared to strengthen over time. The effect of high-technology capital on productivity growth in terms of the value of shipments was fairly small, while its effect on productivity in terms of value added was relatively large. This follows from the fact that raw material (farm) inputs are the major cost component and their use has been increasing because of a combination of scale effects and relative price changes.

[20] See Gibbons (1995) for a comprehensive bibliography on the role of technology in the economy.

Another way to assess the contribution of new technology to productivity and to other performance criteria is to obtain information on the use of such technologies and their effects directly from the industry. Statistics Canada used this approach in its 1993 Survey of Innovation and Advanced Technology in Canadian Manufacturing (Baldwin, Sabourin and Rafiquzzaman 1996). Reported benefits of adopting computer-based technologies, which also applied broadly to the food industry, included increased productivity because of lower labour costs, reduced material consumption and increased equipment utilization rates. The main intangible effect was improved product quality.

The same approach is used in this study. The next section discusses the way plant managers evaluate the general economic impact of new technologies on their operations. Following this, we turn to specific effects on selected aspects of those operations that arise from advanced technology use.

10.2 Economic Impact

An overview of economic impact is provided by the rating that managers of food-processing plants gave to the effects of introducing advanced technologies in each of nine separate functional areas in the five years prior to the survey. These responses provide a broad indicator of how new technologies have influenced the economic performance of plants and hence industries in each of the nine functional areas. Although the rating scale used was 1 (minor impact) to 5 (major impact), we combine these in Table 10A using a three-point scale of low (1 or 2), medium (3) and high (4 or 5) to show the percentage of plants using at least one of the advanced technologies in each functional area that reported a minor, medium or major impact.

The results show that advanced technologies are perceived to have had a substantial economic effect across all functional areas. In eight of the nine areas, substantially more managers see a large economic impact than a small one (Table 10A), however the impact varies by functional area. The area of greatest impact is quality control, which is rated a 4 or 5 by 58% of plants. This is in keeping with the strong emphasis given by firms to a strategy that emphasizes quality. It is followed by processing, process control, and management systems and communications, with 46% to 47% of plants rating them as having a major impact. Materials preparation and handling and pre-processing have the lowest economic impact ratings; pre-processing is the only area in which more managers report a low rather than high impact.

Since a prime motivation for adopting a new technology is its economic impact on plant operations, the anticipated economic impact would be one factor influencing technology adoption rates. Thus, functional areas where the economic impact has been the greatest would be expected, other things being equal, to be the same as the ones with relatively high rates of new technology adoption.

Table 10A: Economic Impact of Advanced Technologies Introduced in Last Five Years

Functional area	Significance			
	Low	Medium	High	N.A.
	percentage of establishments[a]			
Processing	11	21	46	22
Process control	14	25	47	14
Quality control	11	22	58	10
Inventory and distribution	16	24	43	17
Management systems and communications	9	24	46	20
Materials preparation and handling	17	30	31	21
Pre-processing activities	29	26	19	26
Packaging	12	28	44	15
Design and engineering	21	31	40	8

[a] Establishments making the rating as a percentage of those using at least one advanced technology in the respective area.

For the most part, the more highly rated technologies tend to be the ones that are most widely used. For example, processing, process control, and management systems and communications are near the top in both economic impact and adoption rate (that is, the percentage of plants using at least one [illegible] advanced technologies, Table 10B). The main exception is quality control technology, which is [illegible] economic impact and fifth in adoption rate [illegible] expect that the technology with the greatest impa[illegible] would be the one most utilized. As this is not the case here, it could be that the decision to [illegible] not based solely on the expected impact of [illegible] technologies or, it could be that quality [illegible] be achieved through the use of technologies [illegible] than those included in the quality control [illegible] example, through the use of advanced p[illegible] and processing control technologies. [illegible] the regression analysis of the deter[illegible] nology use strongly support this latt[illegible] found that quality practices have a [illegible] the rate of technology adoption in [illegible] ferent areas.

Evaluations of the importance of [illegible] fects of advanced technologies [illegible] Table 10B provides the percentage [illegible] rating a functional technology as ha[illegible] pact by industry breakdown. G[illegible] industry's high use of advanced te[illegible] perhaps not surprising that a greater [illegible] managers in this industry rated the eco[illegible] as major in most areas. In addition, managers in [illegible] "other" and meat industries were more lik[illegible] ceive that advanced technologies [illegible] pact, while this was less likely to hav[illegible] for managers in the bakery industry. Despite these differences, it should be noted that the variation in economic impact ratings across industries is less than the variation in advanced technology usage rates. Industries that have not yet extensively implemented advanced technologies nevertheless have experienced relatively substantial effects from the few that they have introduced to the production process.

Given the relatively high adoption rates of new technologies by larger establishments, it might be expected that they would also be more inclined to rate the economic impact of their advanced technologies as higher. This is indeed the case for processing technologies, management systems and communications, packaging, and for inventory and distribution (Table 10C).

On the other hand, finding differences in incidence [illegible]f use by size class, but no differences in the importance attributed to the technology suggests that differences in usage must then be attributed to another [illegible]or, such as the applicability of the technology or [illegible] differential costs.

[illegible] many cases, ratings of the economic importance [illegible]dvanced technologies are not related to size (for example, quality control, materials preparation and handling, pre-processing, design and engineering) (Table 10C).

[illegible] are only small differences in the ratings of economic impact given by managers of Canadian- and [illegible]ign-controlled plants. The largest differences are [illegible] higher ratings given to the areas of management [illegible]ystems and communications and inventory and

Table 10B: Major Economic Impact of Adv[illegible] Introduced in the Last Five Years by Functional Area

Functional area	Bakery	Ce[illegible]	[illegible]airy	Fish	Fruit and Vegetables	Meat	Other	All
	[illegible]centage of establishments rating impact as high							
Processing	29	[illegible]	56	48	49	43	55	46
Process control	37	[illegible]	56	34	48	47	48	47
Quality control	37	5[illegible]	46	66	52	68	66	58
Inventory and distribution	28	[illegible]	[illegible]2	38	38	46	48	43
Management systems and communications	46	[illegible]	50	33	32	52	53	46
Materials preparation and handling	24	3[illegible]	57	18	29	36	25	31
Pre-processing activities	7	14	26	18	24	17	20	19
Packaging	33	19	38	22	37	49	46	37
Design and engineering	48	34	52	35	49	28	42	39

Table 10C: Major Economic Impact of Advanced Technologies by Size of Establishment

Functional area	Employment Size Group					
	10 - 19	20 - 49	50 - 99	100 - 249	250+	All
	percentage of establishments rating impact as high					
Processing	28	37	42	63	70	46
Process control	36	45	51	51	47	47
Quality control	55	63	47	63	60	58
Inventory and distribution	29	39	33	52	62	43
Management systems and communications	38	45	36	53	62	46
Materials preparation and handling	35	30	26	31	34	31
Pre-processing activities	14	24	15	14	25	19
Packaging	22	21	37	47	53	37
Design and engineering	50	48	21	42	43	39

distribution by foreign-controlled plants, and the relatively higher ratings given to pre-processing activities by Canadian-controlled plants (Table 10D). These are differences that are also strongly related to size.

Table 10D: Major Economic Impact of Advanced Technologies Introduced by Country of Control

Functional area	Canada	Foreign	All
	percentage of establishments rating impact as high		
Processing	46	46	46
Process control	46	52	47
Quality control	58	55	58
Inventory and distribution	41	56	43
Management systems and communications	44	57	46
Materials preparation and handling	31	31	31
Pre-processing activities	20	12	19
Packaging	36	40	37
Design and engineering	39	42	39

10.3 The Relationship of Economic Impact to Plant Characteristics

10.3.1 Introduction

In the previous section, we have shown that the economic impact of the use of advanced technologies is related to the use of technologies and other plant characteristics such as size and nationality of ownership. But the particular effects of variables such as plant size need to be separated from others such as foreign ownership. In this section, we explore this issue in a more rigorous fashion through the use of multivariate analysis.

Using multivariate regression, we examine differences in the characteristics associated with the economic impact attributed to the use of advanced technology. We want to determine whether the impact was greater in establishments that used more technologies, and whether certain other characteristics were also related to the economic impact registered. We examine the characteristics, such as plant size, nationality and industry, which were each investigated separately in the previous section; however, we extend these to include other characteristics like volume and batch operations which have been shown to influence technology use and which may have a separate effect on economic impact. In addition, we ask if certain complementary activities enhance the impact of technology use. Technologies do not exist in a vacuum. Introducing new equipment into a plant may require the reorganization of the plant. The impact may be enhanced by the implementation of certain business practices. In addition, it may be that an R&D unit is critical to a plant's ability to ingest new technologies. Therefore, we examine the effect of certain plant characteristics, technology use, and business practices on the economic impact that managers report that they received. This is done for each of the functional areas.

10.3.2 The multivariate equation

We use the following multivariate equation to investigate these issues:

$$\text{IMPACT} = \alpha_0 + \alpha_1{*}\text{SIZE} + \alpha_2{*}\text{NUTECH} + \alpha_3{*}\text{PRODTYPE} + \alpha_4{*}\text{PRACTICES} + \alpha_5{*}\text{R\&D} + \alpha_6{*}\text{OWNERSHIP} + \alpha_7{*}\text{VOLUME} + \alpha_8{*}\text{BATCH} + \alpha_9{*}\text{INDUSTRY}$$

10.3.3 Dependent variable

IMPACT, the dependent variable, is a binary dependent variable that distinguishes establishments reporting a large economic impact from those not reporting a large economic impact. The dependent variable used for this regression is based on plant managers' evaluations of economic impact. Respondents were asked to rate, on a scale of one to five, by functional area, the economic impact of the introduction of an advanced technology into their plant. The dependent variable takes a value of 1 if the respondent reported 4 or 5 (major impact), and it takes a value of 0 otherwise. Only those establishments using a functional technology are included in the regression for the functional technology.

10.3.4 Explanatory variables

SIZE is the employment size of an establishment, while PRODTYPE measures the production activity of the establishment—primary processing, secondary processing or both. NUTECH measures the intensity of advanced technology use. PRACTICES refers to the business practices used by the firm. R&D measures whether a firm engages in R&D activity. FOREIGN indicates the nationality of ownership of the establishment. VOLUME is included to measure whether the establishment is a high-volume producer. BATCH measures whether a plant's operations are primarily batch or continuous. INDUSTRY was included to capture industry effects.

The set of variables used in the regression, along with their means and standard deviations, is found in Table 10E. Except for the technology intensity variable, the explanatory variables have been defined previously in our multivariate analysis of the determinants of technology use. Included in the [illegible] calculation are those establishments using at least one advanced technology, of any type. The new variable is:

NUTECH —is a continuous variable measuring the number of advanced technologies being used within a functional group. It varies from functional group to functional group. For example, for quality control technologies, it refers to the number of quality control technologies being used by a plant.

10.3.5 Methodology

Logistic regression is used because the dependent variable is dichotomous. The results of the weighted logistic regression are given in Table 10F. Separate results are provided for each functional area—processing, quality control, communications, etc. The omitted category against which the coefficients are calculated is a small, domestic, non-R&D performer that is a primary establishment that does continuous processing and is in the bakery industry. The probability estimates are presented in Table 10G.

10.3.6 Empirical results

Technology use is strongly related to the economic impact. Establishments that use more technologies within a functional area are more likely to have listed the economic impact as being large. This effect is statistically significant for all but processing, distribution and materials handling (Table 10F). Where it is significant, variations of the numbers of technologies used over the range of one standard deviation above and below the means increase the probability of a significant economic effect by at least 20 percentage points, for all but pre-processing technology (Table 10G).

Business practices matter as well. In particular, firms that report having adopted a number of quality-based practices are more likely to indicate that the economic impact of the technologies was large in all areas. These coefficients are significant in seven of the nine technologies: processing, process control, quality control, distribution, materials handling, packaging, and pre-processing. The impact of using these quality-related practices broadly falls between 10 and 20 percentage points, where the effect is statistically significant. Materials and distribution management practices are found to significantly affect the impact of communications technologies. Product and process development practices have less influence on economic impact. Thus, practices have a complementary effect on the advantages of using these technologies. Technologies require certain organizational changes to be used effectively.

On the other hand, having an R&D operation does not enhance the economic impact of the use of advanced technologies, except in the area of communications. While considerable stress has been placed on the importance of R&D facilities, they do not appear to affect the benefits firms receive from the adoption of advanced technologies. This suggests technology development is done outside of R&D units.

Most of the other characteristics are not significantly related to economic impact. Foreign ownership has more negative than positive coefficients. Being a

Table 10E: Summary Statistics for Dependent and Independent Variables for Economic Impact Logistic Regression

Variable	Description	Means	Standard Deviation
1. Dependent variable	Functional Technology		
IMP_PROC	– Processing	0.42	0.49
IMP_PCNT	– Process control	0.38	0.49
IMP_QCNT	– Quality control	0.44	0.50
IMP_INV	– Inventory and distribution	0.30	0.46
IMP_COM	– Management and information systems and communication	0.37	0.48
IMP_HAND	– Materials preparation handling	0.25	0.43
IMP_PRE	– Pre-processing	0.17	0.38
IMP_PACK	– Packaging	0.33	0.47
IMP_DESN	– Design and engineering	0.16	0.37
2. Plant characteristics			
Establishment Size	Employment size		
ESTSIZE1	– 10-19 employees	0.22	0.41
ESTSIZE2	– 20-49 employees	0.27	0.45
ESTSIZE3	– 50-99 employees	0.20	0.40
ESTSIZE4	– 100-249 employees	0.19	0.39
ESTSIZE5	– 250 or more employees	0.11	0.32
Production Type	Processing activity		
PRODTYP1	– primary processing	0.37	0.48
PRODTYP2	– secondary processing	0.23	0.42
PRODTYP3	– both primary and secondary	0.40	0.49
Technology Use	Technological intensity		
NU_PROC	– number of processing technologies used	1.83	2.24
NU_PCNT	– number of process control technologies used	1.53	1.58
NU_QCNT	– number of quality control technologies used	0.63	0.89
NU_INV	– number of inventory technologies used	0.51	0.63
NU_COM	– number of management and information systems and communication technologies used	1.80	1.55
NU_HAND	– number of materials handling technologies used	0.51	0.77
NU_PRE	– number of pre-processing technologies used	0.73	1.01
NU_PACK	– number of packaging technologies used	1.27	1.42
NU_DESN	– number of design and engineering technologies used	0.32	0.67
Ownership	Country of control		
FOREIGN	– foreign owned	0.12	0.33
3. Plant activities			
Business Practices	Business practices		
PRACT_A	– product quality practices	5.11	1.97
PRACT_B	– management practices	2.67	2.19
PRACT_C	– product and process development practices	2.48	2.39
R&D	R&D activity		
RADDOER	– R&D performer	0.64	0.48
Volume of Products	High-volume products		
VOLUME	– percentage of shipments that are high-volume products	63.9	28.5
Type of Operation	Type of operation		
BATCH	– batch versus continuous	0.49	0.50
4. Industry characteristics			
IND_BAKE	Bakery	0.14	0.35
IND_CERE	Cereals	0.15	0.36
IND_DAIR	Dairy products	0.11	0.31
IND_FISH	Fish products	0.14	0.35
IND_VEGG	Fruit and vegetables	0.08	0.27
IND_MEAT	Meat	0.17	0.38
IND_OTHR	Other food products	0.20	0.40

Note: Means and standard deviations refer to the population estimates of technology users.

high-volume producer is not significantly related to the impact derived from the use of advanced technologies. Combining primary and secondary activity is not significantly related to the impact. These characteristics affect technology use, as we have seen in the last chapter; but once technology use is included in the regression, they have no additional effect on overall economic impact.

It is, however, the case that batch operators are significantly less likely to report a major economic impact from the use of advanced technologies. As [illegible] have shown previously, this form of production [illegible]vironment leads to the adoption of fewer advanced technologies; moreover, even when the numbe[illegible] advanced technologies that are adopted by batch op[illegible]erators are taken into account, these technologies have less of an economic impact in batch plan[illegible]

The same story on size emerges from [illegible] bivariate tabulations reported in the previous secti[illegible] There are few technologies where the effect of [illegible] is significantly related to the impact that plant man[illegible]agers associate with the adoption of that technology. The one exception is processing.

The major industry story is associated with pr[illegible]ing, quality control and communications technologies. The cereal, dairy and "other" industries report a significantly higher impact from processing technologies. The meat and fish industries report a [illegible]nificantly higher impact from quality contr[illegible] technologies, while the fruit and vegetable [illegible] industries report a lower than average impact in [illegible]munications technologies.

10.4 Specific Effects of Technology Use

In addition to evaluating the overall economic [illegible] of new technologies used in their plant, managers were asked to assess the impact of these technologies on specific dimensions of productivity gains, product improvement, plant organization, and the ability to meet regulatory requirements. They were also asked about the effects on raw material and labour requirements. Their evaluations indicate the degree to which the use of these technologies has contributed to the success of their business strategies.

10.4.1 Productivity improvement

As discussed earlier, new technologies might be expected to result in the use of less labour, capital or materials per unit of output. Each of these three dimensions of productivity affect unit costs, and all three are considered important by the food industry. In particular, 58% of plants give increased labour productivity a rating of 4 or 5 on the five-point scale, that is, they rate it as being of major importance, while about 42% do so for the productivity of capital and materials (Table 10H).

In addition, reduced set-up time contributes to improved labour and capital productivity. It also allows a faster response to new orders. Forty-five percent of plants consider reduced set-up time to be a very important benefit of new technologies.

One benefit of new technologies in areas such as process control is a lower product rejection rate. This was identified as very important—a score of 4 or 5—by 53% of plants; lower product rejection rates lead to more consistent quality and less waste, and hence contribute to both quality and productivity goals.

10.4.2 Changes in plant organization

Other specific outcomes associated with the adoption of advanced technologies involve changes in plant organization. Such changes might include the rationalization of product lines among a firm's plants, increases or decreases in plant size, and more, or fewer, product lines. Some of these changes also affect a plant's ability to switch among product lines.

Plant managers are about equally divided in their ratings of the effect of new technologies on product-line rationalization among plants. With respect to the effect of advanced technologies on plant size, some 42% do not see smaller plants as a particularly important result, while 11% do. Although somewhat divided, they lean to the view that larger size plants will be the result; 25% believe that this effect is of low importance and nearly 29% believe that larger plants are a very important result. Advanced technology use has a strong positive relationship to plant size and, on balance, the industry sees new technologies as a factor leading to larger plant size.

There is stronger agreement among managers that new technologies contribute to more product lines in the plant. Forty-two percent believe that this is a very important effect. This may be one reason why a large number (60%) believe that increased production flexibility is a very important result of adopting new technology.

Table 10F: Logistic Regression Results for Economic Impact Variable

Variable	Processing	Process control	Quality control	Inventory and distribution	Management systems and communi-cations	Materials prepara-tion and handling	Pre-processing	Packaging	Design and engineering
INTERCEPT	-2.876***	-2.567***	-1.967***	-2.348***	-1.459***	-2.164***	-4.624***	-2.190***	-1.501***
Plant Characteristics									
Establishment Size									
ESTSIZE2	0.296	0.140	0.345	0.539	-0.034	-0.498	1.026	-0.133	0.203
ESTSIZE3	0.540	0.266	-0.443	0.159	-0.554	-0.722	-0.090	-0.115	-0.952
ESTSIZE4	1.252***	-0.021	0.004	0.793	0.198	-0.712	-0.371	0.250	-0.392
ESTSIZE5	1.119**	-0.760	-0.229	0.822	0.073	-0.668	0.257	0.452	-0.377
Technological Intensity									
NU_PROC	0.104	–	–	–	–	–	–	–	–
NU_PCNT	–	0.370***	–	–	–	–	–	–	–
NU_QCNT	–	–	0.534***	–	–	–	–	–	–
NU_INV	–	–	–	0.065	–	–	–	–	–
NU_COM	–	–	–	–	0.304***	–	–	–	–
NU_HAND	–	–	–	–	–	0.021	–	–	–
NU_PRE	–	–	–	–	–	–	0.472***	–	–
NU_PACK	–	–	–	–	–	–	–	0.442***	–
NU_DESN	–	–	–	–	–	–	–	–	1.146***
Ownership									
FOREIGN	-0.598**	0.195	-0.126	-0.049	0.592**	-0.289	-1.240**	-0.384	0.817**
Production Type									
PRODTYP2	0.142	-0.195	-0.452	-0.023	-0.002	0.407	0.309	0.108	0.182
PRODTYP3	0.230	0.244	0.007	-0.051	0.399	0.349	-0.168	0.448*	0.031
Volume of Products									
VOLUME	0.003	0.007	0.002	-0.006	-0.002	0.001	0.003	0.000	0.001
Type of Operation									
BATCH	-0.504**	-0.922***	0.146	-0.637**	-0.430**	-0.894**	-0.673	-0.436*	-0.866**
Plant Activities									
Business Practices									
PRACT_A	0.132*	0.145*	0.156*	0.159*	0.054	0.290**	0.266**	0.147*	0.086
PRACT_B	-0.030	0.050	0.019	0.134	0.115*	0.154	-0.119	-0.102	0.052
PRACT_C	0.201***	0.064	-0.038	0.161**	0.043	-0.086	0.115	0.066	-0.101
R & D Performer									
RADDOER	0.042	0.000	-0.075	-0.267	0.437*	-0.436	-0.925**	-0.396	0.140
Industry									
IND_CERE	0.937**	0.477	0.381	0.855	-0.295	0.467	1.077	0.550	-0.948
IND_DAIR	0.958**	0.417	0.165	0.822	-0.342**	1.202	1.588	0.190	-0.517
IND_FISH	0.615	-0.071	1.359**	0.355	-0.912**	-0.047	1.361	0.335	-0.507
IND_VEGG	0.551	0.032	0.607	-0.101	-1.222***	0.081	1.482	0.636	0.401
IND_MEAT	0.501	0.461	1.329**	0.792	0.036	0.529	0.939	1.286***	-0.860
IND_OTHR	1.002***	0.412	0.994*	0.965*	-0.190	0.071	1.469	0.534	-0.713
Summary Statistics									
N	497	495	328	315	531	280	319	440	200
χ^2	81.5	77.0	27.3	51.4	70.6	37.3	26.7	60.2	31.8
Log Likelihood	-287	-296	-204	-180	-321	-153	-133	-264	-115

Note: *** significant at the 1% level; ** significant at the 5% level; * significant at the 10% level

Table 10G: Estimated Probability of Economic Impact of Adopting Specific Functional Technologies

Variable	Processing	Process control	Quality control	Inventory and distribution	Management systems and communications	Materials preparation and handling	Pre-processing	Packaging	Design and engineering
Plant characteristics									
Establishment Size									
ESTSIZE1	20	31	60	35	45	31	5	45	49
ESTSIZE2	20	31	60	35	45	31	5	45	49
ESTSIZE3	20	31	60	35	45	31	5	45	49
ESTSIZE4	46	31	60	35	45	31	5	45	49
ESTSIZE5	43	31	60	35	45	31	5	45	49
Technological Intensity									
NUTECH	27	31	60	35	45	31	5	45	49
MEAN+SD	27	42	69	35	54	31	8	59	67
MEAN-SD	27	21	50	35	36	31	3	32	31
Ownership									
FOREIGN	18	31	60	35	57	31	2	45	64
NON-FGN	28	31	60	35	42	31	7	45	44
Production Type									
PRODTYP1	27	31	60	35	41	31	5	40	49
PRODTYP2	27	31	60	35	41	31	5	40	49
PRODTYP3	27	31	60	35	51	31	5	51	49
Volume of Products									
VOLUME	27	31	60	35	45	31	5	45	49
MEAN+SD	27	35	60	35	45	31	5	45	49
MEAN-SD	27	27	60	35	45	31	5	45	49
Type of Operation									
BATCH	22	21	60	27	40	22	5	39	36
NO BATCH	32	40	60	41	50	40	5	50	58
Plant Activities									
Business Practices									
PRACT_A	27	31	60	35	45	31	5	45	49
MEAN+SD	32	36	66	42	45	43	8	52	49
MEAN-SD	22	25	54	28	45	22	3	38	49
PRACT_B	27	31	60	35	45	31	5	45	49
MEAN+SD	27	31	60	42	51	31	5	45	49
MEAN-SD	27	31	60	28	39	31	5	45	49
PRACT_C	27	31	60	35	45	31	5	45	49
MEAN+SD	38	31	60	45	45	31	5	45	49
MEAN-SD	18	31	60	26	45	31	5	45	49
R & D Performer									
RADDOER	27	31	60	35	48	31	4	45	49
NON RADDOER	27	31	60	35	38	31	10	45	49
Industry									
IND_BAKE	18	31	44	30	50	29	4	39	49
IND_CERE	36	31	44	30	50	29	4	39	49
IND_DAIR	36	31	44	30	50	57	18	39	49
IND_FISH	18	31	75	30	29	29	4	39	49
IND_VEGG	18	31	44	30	23	29	4	39	49
IND_MEAT	27	31	75	30	50	29	4	70	49
IND_OTHR	37	31	68	52	50	29	4	39	49

Table 10H: Effects of Advanced Technology: Importance by Type of Effect

Effect	Importance			
	Low	Medium	High	N.A.
	percentage of establishments			
Productivity improvement				
Reduced labour requirements per unit of output	9	20	58	13
Reduced material consumption per unit of output	20	24	42	14
Reduced capital (plant and equipment) requirements per unit of output	16	28	43	13
Reduced set-up time	16	25	45	14
Reduced rejection rate	15	18	53	14
Product improvement				
Nutrition	20	23	45	12
Taste or texture or appearance	10	17	62	12
Shelf-life	13	17	59	12
Consumer flexibility or convenience	10	19	60	12
Changes in plant organization				
Firm rationalization of product lines among plants	25	29	26	21
Decreased plant size	42	29	11	18
Increased plant size	25	31	29	15
More product lines	17	27	42	14
Increased production flexibility	9	19	60	12
Higher skill set required	14	31	40	14
Regulatory improvement				
Worker health and safety	6	21	64	9
Food safety	6	12	72	10
Environmental protection	8	22	61	9
Food composition	10	23	56	12

10.4.3 Employee skill requirements

New technologies are often perceived to involve changes in employee skills. Such changes have implications for human resource strategies and plant organization. While automation can reduce the need for some skills (such as in process control and quality testing), the more general result is an increase in skill requirements (Baldwin, Gray and Johnson 1995). In the food industry, 40% of managers believe that the need for a higher skill set is a very important result of new technology, and 14% believe it is of relatively low importance. However, this is not happening everywhere. Somewhat more than half of respondents believe that new technologies have had no effect on these dimensions of employee skill requirements (Table 10H).

In terms of changes in the workforce, more managers (24%) believe that new technologies tend to reduce their ability to substitute less skilled for more skilled personnel than believe the reverse (16%). At the same time, 37% see new technologies resulting in a greater need to substitute more skilled for less skilled personnel; only 9% believe the need has decreased (Table 10I). Taken together, this would indicate that the implementation of advanced technologies in the food-processing sector is increasing skill requirements.

10.4.4 Product improvement

Product quality has at least four dimensions: nutrition; taste, texture or appearance; shelf life; and consumer convenience. The effects of advanced technologies on the last three are deemed to be of major importance by some 60% of enterprises. This is one of the highest percentages of all the effects examined. The effect on nutrition is deemed to be of major importance by 45% of plant managers (Table 10H). These ratings are consistent with the emphasis on the goal of improved product quality discussed in the chapters on strategies, practices and technology adoption rates.

10.4.5 Regulatory improvement

As noted in the sections on industry characteristics and business practices, food safety is basic to all food-processing operations and is subject to government regulation. Also, labelling regulations require that product characteristics such as ingredient and nutrient composition, volume and weight be accurately reported. In addition, plants must meet regulations concerning worker health and safety, and environmental protection.

More plants consider an improved ability to meet or exceed government regulatory requirements to be of major importance than any other effect of advanced technology. In particular, 72% do so for improved food safety. The goal of many new technologies is to improve both safety and quality (taste, texture and appearance). In addition, 56% rated an improved ability to meet food compositional standards to be of major importance.

Sixty-four percent of managers report that an improved ability to meet worker health and safety regulations and environmental protection requirements are important results of adopting new technologies.

10.4.6 Input requirements

Just as new technologies and practices may allow plants to better tailor products to consumer demand they may also impose additional demands on suppliers of raw products. Possible effects on input or raw-product demand are a greater need for uniform and consistent quality, timeliness of delivery and specific attributes such as composition and size. Demand to these characteristics might be changed, as might its ability to substitute less expensive for more expensive raw materials and in its need to import supplies.

More than 40% of establishments report that using advanced technologies has resulted in a need for more uniform and consistent raw-product quality, and timeliness of delivery (Table 10I). However, almost all the rest see no effect. Thirty-nine percent indicate an increased need for specific raw product attributes such as composition and size, while 59% say there is no effect on such characteristics. These differences in ratings would be related to the kinds of raw products and final products produced, as well as the kinds of new product and process innovations adopted.

While 24% of plant managers believe that new technologies have increased their ability to substitute less expensive for more expensive raw products, 70% see no effect. Eighty-three percent see no change in the need to import raw products.

10.5 Summary and Conclusions

Advanced technologies are adopted to improve the economic performance of plants or firms by increasing productivity and producing higher quality products. In the aggregate, they contribute to industry performance and overall economic welfare.

Plant managers rate the economic impact of new technologies as highest in quality control, processing, process control and communications. In keeping with the central role given to the strategy involving quality enhancement, advanced technologies are assessed as having the greatest importance in the area of quality control.

For the most part, the technologies that are rated as having the greatest impact are also the ones that are the most widely used. It is, therefore, significant that in some functional areas (such as processing, inventory and distribution), larger plants are more likely to give high ratings to economic impact than smaller plants, while in about half the areas (for example, quality control), there is little or no relationship between ratings and plant size. In cases such as design and engineering, materials preparation and handling, and process control, larger and smaller plants agree on the effects of new technologies, but a smaller proportion of the small plants use them. This could reflect differences in the applicability of the technologies, or some other factor affecting their use.

Differences in the rankings of economic impact by country of control are relatively small. This suggests that foreign/domestic differences in technology use are not strictly related to differences in applicability or impact. Rather they must relate to another factor such as differences in the costs of adopting technologies.

It is also important to note that there are complementary business practices that enhance the economic impact of technologies. The use of quality-related business practices is strongly related to economic impact across a wide range of technologies. This confirms the contribution that many different technologies can make to quality improvement—especially when complemented by a set of business practices aimed at quality enhancement. Technological and organizational change, at least as measured by these practices, work hand in hand.

Table 101: Effect of Advanced Technologies on Selected Input Requirements

Input	Use has: Increased	Use has: Decreased	Use has: No effect
	% of establishments		
Raw materials			
Need for uniform and consistent quality	49	3	48
Need for timeliness of delivery	44	3	54
Need for specific attributes (size, composition, etc.)	39	3	59
Ability to substitute less expensive for more expensive raw materials	24	7	70
Need to substitute imported for domestic raw materials	11	7	83
Labour			
Ability to substitute less skilled for more skilled personnel	16	24	59
Need to substitute more skilled for less skilled personnel	37	9	54

More specific effects of advanced technology adoption include improvements in productivity, products and regulatory compliance. Overall, effects in the areas of product quality improvement and regulatory compliance have the largest impact. Improved food safety is the most important of all. The most significant effects on productivity are reduced labour requirements per unit of output, and a reduced rejection rate.

Chapter 11 – Technological Competitiveness

The data presented in the previous chapters provide an overview of the incidence, intensity and effect of advanced technology use in the food-processing industry. They reveal the extent to which Canadian plants are making use of what is perceived to be an important input into the manufacturing process.

Information on technology use becomes even more valuable if there is a metric or standard that can be applied to determine desirable levels of technology use. Since technology is seen as critical to Canada's competitiveness, we use a measure of technological competitiveness in this chapter as a reference point to evaluate levels of technology use.

The competitiveness of nations and firms has garnered much attention lately. Being competitive at the domestic and, increasingly more importantly, at the global level, is important for the development and growth of firms and nations. A technology strategy is one of the key elements of a firm's competitiveness (Nelson 1986).

The technological competitiveness of a country can be evaluated in two ways. One is to compare the incidence of technology use across countries as was done by McFetridge (1992) in his study of the Canadian and U.S. manufacturing sectors in the late 1980s. The other is to have plant managers evaluate their production technology against that of their competitors, both domestic and foreign. Both methods were followed by Baldwin and Sabourin (1997) in their study of the Canadian and U.S. manufacturing sectors in the early 1990s. In this study, we focus solely on the second method, since data on U.S. technology use that are comparable to those derived from our Canadian survey are not available.

The advantage of this approach is twofold. First, it makes use of the evaluation of managers, who are experts in the field. Their responses should produce reliable estimates because, in order to remain in business, firms must constantly assess their capabilities and strategies against those of their immediate competitors, as well as against industry leaders. Baldwin and Sabourin (1997) successfully used this approach in a study that compared technology use in Canada and the United States. Their study, which used both self-evaluation and technology use data, found that the technology use data confirmed the self-evaluation data.

Second, a self-evaluation by managers provides a more comprehensive evaluation of technological competency than does data on incidence of technology use, since it is based on a wide range of technological characteristics and processes. Comparisons based solely on technology use, such as whether Canadian plants are more likely to use advanced thermal preservation technologies, provide only a partial measure of technological competitiveness. Technological competitiveness involves many dimensions, of which incidence of technology use is but one. It also involves intensity of use, plant practices and organization. By asking plant managers to provide such a comparison, we are relying on their own understanding of what it takes to be technologically advanced.

The rest of this section concentrates on the differences between more and less advanced plants based on measures of competitiveness. Plant managers evaluated their production technologies against those of their most significant competitors both inside and outside Canada. They did so using a five-point scale: 1—much less competitive; 2—less competitive; 3—about the same; 4—more competitive; and 5—much more competitive. For the purposes of this study, results for this question have been aggregated into three categories. Scores of 1 and 2 are treated as less competitive, scores of 4 and 5 as more competitive, and a score of 3 as about the same. Differences in the technological incidence and intensity of the two extreme groups—the more- and the less-competitive groups—are investigated here. This not only provides a metric that can be used to provide a picture of what is competitive; it also allows us to evaluate which technologies plants consider to be important when they assess their overall competitiveness.

We proceed first by looking at the functional areas that are perceived to be more or less competitive, then at how the variations in technology use, the economic impact and the perceived shortcomings relate to the competitive position of plants. This allows us to assess which technologies most affect competitiveness. Finally, we turn to examine the

Table 11A: Competitive Ranking Against Other Producers

Location of competitors	More competitive	Same	Less competitive	Not applicable
	percentage of establishments			
Other producers in Canada	29	42	20	10
Producers in the U.S.	23	30	26	22
Producers in Europe	14	26	28	33
Other foreign producers	20	24	16	40

determinants of competitiveness using multivariate analysis.

11.1 Technology Rankings

Compared with other domestic producers, most managers (42%) consider their production technologies to be as competitive, that is, the same as those of their competitors (Table 11A). Slightly more report being more competitive (29%) than less competitive (20%). This slight asymmetry is consistent with the fact that the smallest plants—those with fewer than 10 employees—are outside the scope of the survey and are less likely to use advanced technology than are larger plants.

The same symmetric distribution of the self-assessed competitive advantage does not exist against foreign competition. Compared with U.S. producers, a slightly larger proportion of establishments report being less competitive (26%) than more competitive (23%). The disadvantage is even greater with respect to European producers. Some 28% of Canadian managers feel they are behind these competitors, compared with only 14% who feel they are ahead. About 25% to 30% of plants consider their technologies to be equal to those of their foreign competitors, roughly 15 percentage points lower than that reported for domestic competitors.

It is important to examine how the more and less competitive establishments are distributed across industry, size and ownership groups in order to find out whether the differences associated with being more or less competitive merely capture size or industry effects. If, for example, it is only the large plants that consider themselves to be more competitive and the small plants that consider themselves less competitive, then the technological competitiveness measure primarily captures size effects. It is still a useful measure of differences—but differences would be primarily related to size differences. Similarly, if all or most of the more competitive establishments were found to be in one or two industries, with the less competitive concentrated in other industries, differences in technological competitiveness would be mainly associated with industry effects.

In order to determine whether the competitiveness measure captures something other than pure industry, size and ownership effects, we present frequency distributions of the more- and less-competitive establishments by size, industry and ownership (Table 11B). More detailed examination of these issues is reserved for the multivariate analysis in a later section of this chapter.

More of the largest establishments (84%) than the smallest (37%) feel they are at least as competitive as their U.S. competitors. However, collectively these two groups account for only about one-third of our target population.[21] The majority of the population are small and medium-sized plants with between 20 and 249 employees. In this group, more establishments feel less than more competitive, but the difference is not large. We can conclude from this that our technological competitiveness measure, although related to size, is more than just a proxy for size. In addition, while advanced technology use at the food industry level increases monotonically with size, technological competitiveness appears to do so only weakly over the mid-size range.

An examination of differences across industries reveals roughly equal distributions of more and less competitive plants in the bakery, cereal and "other" industries. In each case, the percentage of plants in the more competitive group is about the same as in the less competitive group. A greater percentage feel they are less competitive than those that feel they are more competitive in the dairy, meat and fruit and vegetables industries, while the reverse is found in the fish products industry. Our measure of technological competitiveness does not just reflect industry differences.

[21] Establishments with fewer than 10 employees are excluded from the target population.

Table 11B: Distribution of Technological Competitiveness Assessment Evaluated Against U.S. Producers

Establishment characteristics	Competitiveness			
	More competitive	Same	Less competitive	N. A.
	percentage of establishments			
Size				
10–19 employees	12	25	29	35
20–49	22	25	29	24
50–99	24	30	28	19
100–249	24	38	23	15
250+	4[illegible]	40	11	4
Industry				
Bakery	19	24	21	35
Cereal	23	39	23	15
Dairy	27	22	37	15
Fish	27	[illegible]	11	25
Fruit and vegetables	19	37	29	15
Meat	19	20	37	25
Other	[illegible]	[illegible]	25	17
Country				
Canada	21	[illegible]	27	24
Foreign	36	[illegible]	14	7
All establishments	2[illegible]	[illegible]	26	22

As for ownership effects, a greater percentag[illegible] Canadian-owned plants feel that they are less [illegible] petitive than those that feel they are more com[illegible] tive, while the reverse is true for foreign-owned plants. Most foreign-owned plants, however, feel t[illegible] are the same as their U.S. competitors. Our measu[illegible] therefore, captures more than just ownership effe[illegible] though it is partially related to it.

11.2 Technological Competitiveness Measure

This section examines differences in technolog[illegible] between the more and less competitive plants. [illegible] amining the differences in the technological characteristics of these two extreme groups serves [illegible] provide insights into the relationship between com petitiveness and technological capability.

We are interested in establishing which technologies plant managers consider to be crucial to evaluating themselves as being more competitive. There are two ways in which this can be done.

First, we examine which functional areas are used more intensely by the more competitive and the less competitive groups. In doing so, we use incidence of technology use. However, we recognize that technological competence is not based solely on the use [illegible] single technology or even on the use of several [illegible]ologies. Rather it depends on how the technolo[illegible]e being applied.

[illegible] overcome this potential deficiency, we employ a [illegible]ond measure—the extent to which major deficien[illegible]e perceived to exist in particular functional ar[illegible] This measure is used to identify the areas in [illegible] more competitive plants feel that they have [illegible]roblems and the areas in which they still have [illegible]blems. This provides us with another way to de[illegible]ermine which technologies are crucial for a firm's competitiveness. Areas in which more competitive plants feel especially *disadvantaged* obviously contribute little to a plant's overall competitiveness assessment.

What then marks more competitive from less competitive plants in terms of usage? To determine this, [illegible] first determine the 'core' technologies for the more competitive plants by examining which technologies have the highest adoption rates by these plants. Second, we investigate the areas where there are the greatest differences in adoption between the more and less competitive groups.

Process control, management systems and communications, and processing have the highest adoption rates by more competitive plants, all greater than 70%

Table 11C: Differences in Technological Charcteristics between More- and Less-Competitive Establishments

	Technology Use			NOT Disadvantaged		
	More competitive	Less competitive	Difference	More competitive	Less competitive	Difference
	percentage of establishments		*percentage points*	*percentage of establishments*		*percentage points*
Process control	77	52	25	77	48	29
Management systems and communications	75	61	14	62	51	11
Processing	73	61	12	81	46	35
Packaging	61	52	9	83	57	26
Pre-processing	56	25	31	88	73	5
Inventory and distribution	49	38	11	64	64	0
Quality control	48	31	17	89	71	18
Materials preparation and handling	46	23	23	81	65	16
Design and engineering	33	11	22	70	52	18

(Table 11C). This is followed by packaging and pre-processing at 61% and 56%, respectively. The least-used technologies are design and engineering technologies with adoption rates of only 33%.

Turning to differentials, the more competitive plants are more likely to use at least one technology from each of the nine functional groups. The greatest differences are found for pre-processing, process control, automated materials handling, and design and engineering technologies with differences of 31, 25, 23, and 22 percentage points, respectively.

Next we investigate the areas in which managers feel further progress must be made because they still suffer significant technological disadvantages in relation to their competitors.

The percentage of managers who feel they suffer a technological disadvantage provides an alternate measure that can be used to gauge the areas that matter most in evaluating technological competitiveness. This measure has the advantage that it is more inclusive than the incidence variable. It captures more than just the existence of an advanced technology.

If managers consider a plant to be generally competitive, but recognize that it is behind in a particular area of technology, they implicitly do not perceive this area to be very important to their overall competitiveness. They downplay the importance of this particular area in their overall competitive assessment. Areas in which more competitive firms feel especially disadvantaged obviously contribute less to their overall competitiveness assessment. This means that we can draw inferences about which areas managers feel are most important for their competitiveness assessment by examining where disadvantages are least for those who assess themselves as more competitive.

When a manager assesses the existence of a major deficiency, he takes into account the incidence of technology use as well as many other factors—the intensity, the appropriateness of the technologies, how they are integrated into the plant, and the capabilities of his staff. It is therefore possible that the relationship between this alternate measure and the competitiveness of a plant varies from the previous relationship between incidence and competitiveness.[22]

More competitive establishments feel least disadvantaged in the areas of quality control, pre-processing, packaging, processing and materials handling. In other words, very few competitive establishments (between 10% to 20%) feel they are at a disadvantage against their competitors in these areas (Table 11C). Rather, it is in the areas of management systems and communications, and inventory and distribution in which they feel especially disadvantaged.

Using this logic, we conclude that the more-competitive managers heavily weight the state of their plants' processing, pre-processing, quality control, packaging, and materials handling technologies, when evaluating their overall competitiveness ranking. Inventory and distribution, management systems and

[22] While this alternate variable has potential advantages, it suffers the disadvantage of not being as precise a measure as technology use and, therefore, containing more subjective judgement.

communications, and design and engineering, on the other hand, are given less weight in their overall calculations.

As might be expected, less competitive establishments generally feel more disadvantaged than their more competitive counterparts. The less-competitive establishments feel most disadvantaged when it comes to processing, process control, management systems and communications, and design and engineering technologies.

To this point, we have used a number of criteria to try to ascertain which technologies are key components for a technologically "competitive" plant. We have chosen four—the incidence of functional technology use by the more competitive plants; the difference in this use between the more and less competitive plants at the functional level; the technological disadvantage for the more competitive plants; and the difference in technological disadvantage between the more and less competitive groups. Each criteria, by itself, only provides a partial picture. In order to provide a more comprehensive assessment we employed a ranking scheme. Each of the functional technology groups was assigned a rank for each of the four criteria. For example, technology use for the more competitive plants was ranked according to the percentage of establishments that had adopted it. According to this scheme, process control was ranked first, followed by management systems and communications, and then processing (Table 11D) reflecting adoption rates of [illegible] and 73% respectively (Table 11C).

The ranks for each functional group were then summed to obtain an overall rank score. The lower the total rank score, the more critical the technology. (Table 11D). Processing, process control, pre-processing and quality control are ranked highest. At the other end of the scale is design and engineering, and inventory and distribution. This suggests that processing technologies—processing, process control, and pre-processing—and quality control technologies are key ingredients to having a 'competitive' plant.

11.3 Multivariate Analysis of Competitive Position

11.3.1 Introduction

The evidence presented in the previous sections indicates that the technological profiles of more- and less-competitive establishments differ in many respects. More-competitive establishments are more likely to use an advanced technology, to adopt greater numbers of them, and to generally feel that they have fewer technological deficiencies. In this section, we explore this issue in a more rigorous fashion through the use of multivariate analysis. Using logistic regression, we examine differences in the characteristics associated with these two groups. We ask which technologies are related to a more-competitive ranking and whether certain other plant characteristics, like nationality, are also related to the competitive label.

11.3.2 The multivariate equation

In order to investigate the relationship between competitiveness and plant characteristics, we use:

$$\begin{aligned} \text{TECHCOMP} = {} & \alpha_0 + \alpha_1 {*}\text{SIZE} + \alpha_2 {*}\text{TECHNOLOGY} \\ & + \alpha_3 {*}\text{PRODTYPE} + \alpha_4 {*}\text{PRACTICES} + \alpha_5 {*}\text{R\&D} \\ & + \alpha_6 {*}\text{OWNERSHIP} + \alpha_7 {*}\text{VOLUME} \\ & + \alpha_8 {*}\text{ADVANTAGE} + \alpha_9 {*}\text{BATCH} \\ & + \alpha_{10} {*}\text{INDUSTRY} \end{aligned}$$

11.3.3 Dependent variable

TECHCOMP is a binary dependent variable differentiating more- and less-competitive establishments. It is based on the competitiveness self-evaluation score provided by plant managers in relation to their U.S. competitors. It takes a value of 1 if the plant's production technology is more competitive than that of their U.S. competitors, and a value of 0 if it is less technologically competitive than their U.S. competitors.

Table 11D: Ranking of Technology Use and Technological Disadvantage by Functional Group

Functional group	Technology Use		NOT Disadvantaged		Total Rank Score	Overall Rank
	More competitive	Difference (more vs. less)	More competitive	Difference (more vs. less)		
Process control	1	2	6	2	11	1
Management systems and communications	2	6	9	7	24	7
Processing	3	7	4	1	15	2
Packaging	4	9	3	3	19	5
Pre-processing	5	1	2	8	16	3
Inventory and distribution	6	8	8	9	31	9
Quality control	7	5	1	4	17	4
Materials preparation and handling	8	3	4	6	21	6
Design and engineering	9	4	7	4	24	7

11.3.4 Explanatory variables

The dependent variables are mainly those used previously. Size is the employment size of a plant. Prodtype measures the production activity of the establishment—primary processing, secondary processing or both. Technology measures the incidence and/or intensity of advanced technology use. Practices refers to the business practices used by the firm. R&D measures whether a firm engages in R&D activity. Ownership indicates whether the establishment is foreign-owned. Volume is included to measure whether an establishment is a high-volume producer. Advantage measures the extent to which establishments feel they do not have a technological disadvantage. Batch measures whether a plant's operations are primarily batch or continuous. Industry was included to capture industry effects.

With the exception of the two variables—technology use and technological advantage—the explanatory variables have been described in detail above. The set of variables used in the regressions, along with their means and standard deviations for the data set used in the regression, is found in Table 11F. The new variables are:

Technology use. Advanced technology use is represented by a set of binary variables that captures incidence of use for each of the nine functional technologies. Each variable is assigned a value of 1 if the establishment uses at least one technology from that functional group, and a value of 0 otherwise. For example, if an establishment is using either electronically controlled machinery (integrated or non-integrated) or some form of electronic detection of machinery failure, then the variable capturing materials preparation and handling technologies will be assigned a value of 1.

Technological advantage. To capture the technological status of different functional areas, the technological advantage variable is defined as the percentage of establishments that did *not* feel they suffered from a technological disadvantage, in other words, that were satisfied that they were at least as good as other firms in this area. This variable will be positively related to the competitiveness score in areas that managers feel are essential to their competitive position.

11.3.5 Estimation Methods

The results of the weighted logistic regression that estimates the probability of a firm being more competitive rather than less competitive are given in Table 11G. The omitted category against which all but the industry coefficients are calculated is a small, domestic, non-R&D performer that is a primary establishment in the bakery industry, and that does continuous processing. As before, both the coefficients (column 1) and the probabilities (column 2) are provided.

11.3.6 Empirical results

As described previously, the competitiveness score is related to several key areas—process control and packaging—where firms feel they are not technologically disadvantaged. The overall competitiveness scores provided by managers are positively and significantly related to whether they do not feel disadvantaged in these two areas. Establishments that believe their process control and packaging technology to be at least as good as their competitors add 30 and 20 percentage points, respectively, to the likelihood that they consider themselves to be more competitive than their foreign competitors.

Table 11F: Summary Statistics for Dependent and Independent Variables for More- and Less-competitive Logistic Regression

Variable	Description	Means	Standard deviation
1. Dependent Variable	*Technological competitiveness*		
TECHCOMP	– more or less technologically competitive	0.47	0.50
2. Plant Characteristics			
Establishment Size	Employment size		
ESTSIZE1	– 10-19 employees	0.20	0.40
ESTSIZE2	– 20-49 employees	0.30	0.46
ESTSIZE3	– 50-99 employees	0.21	0.41
ESTSIZE4	– 100-249 employees	0.17	0.38
ESTSIZE5	– 250 or more employees	0.12	0.32
Production Type	Processing activity		
PRODTYP1	– primary processing	0.35	0.48
PRODTYP2	– secondary processing	0.22	0.41
PRODTYP3	– both primary and secondary	0.43	0.50
Ownership	Country of Co[illegible]		
FOREIGN	– foreign owned	0.11	0.32
Functional Technology Incidence	Technolog[illegible]		
QUALITY	– quality control	0.40	0.49
COMMUNIC	– management and information systems and communications	0.70	0.46
DESIGN	– design and engineering	0.21	0.41
DISTRIB	– inventory and distribution	0.43	0.50
MATERIAL	– materials preparation and handling	0.34	0.48
PACKAGE	– packaging	0.58	0.50
PROCCNTL	– process control	0.64	0.48
PREPROC	– pre-processing	0.40	0.50
PROCESS	– processing	0.67	0.47
Functional Technology Advantage	Te[illegible]		
ADV_PROC	– processing	0.55	0.50
ADV_PCNT	– process control	0.54	0.50
ADV_QCNT	– quality control	0.74	0.44
ADV_INV	– inventory and distribution	0.58	0.49
ADV_COM	– management and information systems and communications	0.48	0.50
ADV_HAND	[illegible]	0.60	0.49
ADV_PRE	[illegible]	0.62	0.49
ADV_PACK	[illegible]	0.59	0.49
ADV_DESN	[illegible]	0.45	0.50
3. Plant Activities			
Business Practices	Business practices		
PRACT_A	– product quality practices	5.00	2.00
PRACT_B	– management practices	2.64	2.18
PRACT_C	– product and process development practices	2.49	2.36
Research and Development	R&D activit[illegible]		
RADDOER	– R&D performer	0.67	0.47
Volume of Products	High Volume Products		
VOLUME	– percentage of shipments that are high-volume products	62.9	28.5
Type of Operation	Type of Operation		
BATCH	– batch versus continuous	0.52	0.50
4. Industry Characteristics			
IND_BAKE	Bakery	0.12	0.33
IND_CERE	Cereals	0.14	0.35
IND_DAIR	Dairy products	0.13	0.34
IND_FISH	Fish products	0.12	0.32
IND_VEGG	Fruit and vegetables	0.07	0.26
IND_MEAT	Meat	0.22	0.41
IND_OTHR	Other food products	0.20	0.40

Note: Means refer to population estimates.

Table 11G: Logit Regression Results for More and Less Competitive Dependent Variable

Variable	Coefficient (1)	Probability (2)
INTERCEPT	-1.11	–
Plant Characteristics		
Establishment Size		
ESTSIZE1	–	49
ESTSIZE2	-0.10	49
ESTSIZE3	-0.13	49
ESTSIZE4	-0.42	49
ESTSIZE5	0.96	49
Functional Technology Incidence		
PROCESS	0.04	49
NO PROCESS	–	49
PROCCNTL	0.95 **	58
NO PROCCNTL	–	34
QUALITY	0.19	49
NO QUALITY	–	49
DISTRIB	0.02	49
NO DISTRIB	–	49
COMMUNIC	-0.10	49
NO COMMUNIC	–	49
MATERIAL	-0.12	49
NO MATERIAL	–	49
PREPROC	0.99 ***	64
NO PREPROC	–	39
PACKAGE	-0.66 *	42
NO PACKAGE	–	59
DESIGN	0.45	49
NO DESIGN	–	49
Functional Technology Advantage		
ADV_PROC	0.48	49
NO ADV_PROC	–	49
ADV_PCNT	1.28 ***	63
NO ADV_PCNT	–	33
ADV_QCNT	-0.19	49
NO ADV_QCNT	–	49
ADV_INV	-0.80 **	41
NO ADV_INV	–	61
ADV_COM	0.52	49
NO ADV_COM	–	49
ADV_HAND	-0.10	49
NO ADV_HAND	–	49
ADV_PRE	0.17	49
NO ADV_PRE	–	49
ADV_PACK	0.76 **	57
NO ADV_PACK	–	38
ADV_DESN	-0.29	49
NO ADV_DESN	–	49
Ownership		
FOREIGN	0.66	49
DOMESTIC	–	49
Business Practices		
PRACT_A	0.14	49
MEAN+SD	–	49
MEAN-SD	–	49
PRACT_B	-0.12	49
MEAN+SD	–	49
MEAN-SD	–	49

Table 11G: Logit Regression Results for More and Less Competitive Dependent Variable – *(Concluded)*

Variable	Coefficient (1)	Probability (2)
PRACT_C	0.06	49
MEAN+SD	–	49
MEAN-SD	–	49
R&D		
RADDOER	-0.04	49
NON RADDOER	–	49
Production Type		
PRODTYP1	–	49
PRODTYP2	-0.05	49
PRODTYP3	0.52	49
Volume of Products		
VOLUME	0.02	49
MEAN+SD	–	49
MEAN-SD	–	49
Type of Operation		
BATCH	-1.21 ***	35
NO BATCH	–	65
Industry Characteristics		
IND_BAKE	–	67
IND_CERE	-0.31	67
IND_DAIR	-1.83 ***	25
IND_FISH	0.15	67
IND_VEGG	-1.43 **	33
IND_MEAT	-1.82 ***	25
IND_OTHR	-0.10	67
Summary Statistics		
N	392	392
χ^2	119.1	–
Log Likelihood	-183	–

Note: *** significant at the 1% level; ** significant at the 5% level; * significant at the 10% level

But the competitiveness score is also related to incidence of use, even when the overall competency is considered. Establishments using process control and pre-processing technologies are significantly more likely to consider themselves to be more competitive. Both add about 25 percentage points to the probability of being more competitive. On the other hand, the variable that captures the incidence of packaging technology is negatively related to the competitiveness assessment. Therefore, the overall competency in packaging has a positive coefficient but the incidence of packaging has a negative coefficient. This suggests that effectiveness in this area is unrelated to the particular set of technologies that were used in the survey.

Although the coefficient attached to the largest size class is positive, it is not statistically significant. The significance of this size group disappears after controlling for continuous type operations. Thus, large continuous-type operations are more likely to be competitive. Having continuous rather than batch operations increases the probability of being competitive by 30 percentage points.

Business practices aimed at enhancing product quality are positively related to being more competitive, however, the result is not statistically significant. Materials and distribution management practices, on the other hand, are negatively related to the competitiveness ranking, but they too are not statistically significant.

Earlier in this chapter, we found that simple tabulations of competitiveness scores against ownership indicated that foreign-owned plants are more likely to evaluate themselves as more advanced than less advanced, while the reverse is found for domestic-owned plants. Based on this, one might conclude that foreign-owned plants are more competitive. However, controlling for plant and industry characteristics, we find the coefficient on foreign ownership is positive but not statistically significant. Differences in competitiveness scores between

domestic and foreign plants reflect differences in their types of operations, technology use, and products produced.

Establishments in the dairy, meat, and fruit and vegetable industries are significantly less likely to consider themselves more competitive. Establishments in these three industries are between 30 and 40 percentage points less likely to consider themselves competitive compared with establishments in the other industries. Thus, industries that were shown previously to be more intensive technology users are not necessarily the most competitive.

11.4 Conclusion

In conclusion, there is a distinct group of plants that are more technologically competitive than their foreign counterparts. This group consists of continuous operation plants using process control and pre-processing technologies. They are also plants that consider their process control and packaging technology to be the equal of their competitors. Of interest, plants in industries with the most intense technology use (dairy, meat and fruit and vegetable) do not generally rank themselves at the top in relation to their foreign competitors. Indeed, the dairy and meat industries consider themselves generally to be behind their competitors.

It is noteworthy that there is no close relationship between these technology competitiveness rankings and the relative rates of advanced technology use at the industry level. High technology use does not necessarily guarantee competitiveness at the industry level. This partly reflects the fact that there are substantial differences in the degree of sophistication of the various U.S food-processing industries that are reflected in Canada. The industries with a higher intensity of technology use in the United States also have a higher intensity of use in Canada.

Chapter 12 – Technology Upgrade Plans

The use of technology does not stand still. We should expect that firms will react to their perceptions of existing deficiencies and future needs by upgrading their technologies. This chapter examines firms' plans to improve the technology they use and the factors that influence these plans.

In order to gauge the future changes that firms expect to implement, managers were asked to describe their plans to upgrade their plant's technology over the next three years. The options provided were: 1) no plans for change; 2) plans under consideration; 3) plans for a minor replacement (less than 25%); 4) plans for a major replacement (25% to 74%); and 5) plans for a complete replacement (75% to 100%). Roughly 30% of establishments report either no plans, plans under consideration or plans for a minor upgrade, while 12% plan a major upgrade. A negligible number are planning a total replacement of existing technologies (Table 12A). This indicates that technological change tends to be incremental at the individual plant level.

The larger the plant, the more likely it is to have plans for a minor or major upgrade. In particular, 47% of plants with 250 or more employees plan a minor change, and 24% plan a major change. Foreign-controlled plants are appreciably more likely than Canadian-controlled plants to have plans for a minor upgrade, and a little more likely to be planning a major upgrade.

12.1 Analysis of Technology Upgrading Plans

To more fully investigate the extent to which these relationships hold, we use multivariate regression analysis to investigate the relationship between intentions to upgrade technology and various plant characteristics. In particular, we investigate whether upgrading is likely to be more intensive in those plants that already are more technologically advanced and whether it is affected by the degree to which plants feel they are disadvantaged, as well as other characteristics of a technical nature, such as volume or batch characteristics. We estimate the following equation:

$$
\begin{aligned}
\text{UPGRADE} = {} & \alpha_0 + \alpha_1{*}\text{SIZE} + \alpha_2{*}\text{OWNERSHIP} \\
& + \alpha_3{*}\text{TECHNOL} + \alpha_4{*}\text{PRODTYPE} + \alpha_5{*}\text{VOLUME} \\
& + \alpha_6{*}\text{BATCH} + \alpha_7{*}\text{DISADV} + \alpha_8{*}\text{PRACTICES} \\
& + \alpha_9{*}\text{INDUSTRY}
\end{aligned}
$$

12.1.1 Dependent variable

UPGRADE is a binary dependent variable that represents the amount of upgrading taking place. It is measured by three different dependent variables to capture different states of upgrading.

The first (REP_LOTS) is a binary variable that is 1 if there is a major upgrade or total replacement planned, and 0 if there are no plans, or if plans are only under consideration. It will be used to investigate the variables that distinguish between no plans and very aggressive replacement intentions.

The second (REP_BIT) is a binary variable that is 1 if there is a minor upgrade planned, and 0 if there are no plans, or if plans are only under consideration. It will be used to investigate the variables that distinguish between no plans and incremental replacement intentions.

The third (LOTS_BIT) is a binary variable that is 1 if there is a major upgrade or total replacement planned, and 0 if there a minor upgrade planned. It will be used to investigate the variables that distinguish between an aggressive replacement policy and incremental replacement intentions.

12.1.2 Explanatory variables

The explanatory variables are much the same as before. SIZE is the employment size of a firm, while OWNERSHIP indicates the nationality of ownership of the establishment. TECHNOL measures the intensity of advanced technology use. PRODTYPE measures the production activity of the establishment—primary processing, secondary processing or both. VOLUME is included to measure whether an establishment is a high-volume producer. BATCH measures whether a plant's operations are primarily batch or continuous. DISADV captures the extent to which the plant believes

Table 12A: Plans to Upgrade Technology

	Plans				
	None	Being considered	Minor <25%	Major (25 -74%)	Complete (75%+)
	percentage of establishments				
Food industry	29	30	29	12	–
Size (employees)					
10 - 19	42	30	18	11	–
20 - 49	34	28	27	11	–
50 - 99	25	38	27	10	–
100 - 249	20	31	38	11	–
250+	8	17	47	24	3
Control					
Canada	30	31	27	12	–
Foreign	20	23	42	15	–

* – Indicates negligible.

it suffers a technological disadvantage. PRACTICES refers to the business practices used by the firm. INDUSTRY was included to capture industry effects. A summary of these variables along with the means and standard deviations for the sample used for the regression is provided in Table 12B. With the exception of the technology and disadvantage variables, the explanatory variables have previously been defined. The new variables are:

Technology use. Advanced technology use is represented by a variable that captures the number of advanced technologies used across all functional groups.

Disadvantage. The disadvantage that a firm faces is derived from the variable that was used to capture the extent to which a firm felt it faced a significant technological disadvantage. If a firm scored itself as disadvantaged (on a scale of 1 to 5 as either a 4 or 5 in a particular technology), then it was defined to be disadvantaged in that technology. Our explanatory variable is the number of technologies where this occurs and is a continuous variable that runs from 0 to 9—the number of technology classes.

12.1.3 Estimation methods

The results of the weighted logistic regression estimating the probability of varying degrees of upgrades are given in Table 12C.[23] The first column examines the major upgrade versus no replacement decision; the second column examines the minor upgrade versus no replacement decision; the third column examines the major as opposed to minor replacement decision. The omitted category is a small, domestic, primary processing establishment in the bakery industry that does continuous processing.

12.1.4 Empirical results

The multivariate regression confirms that plants that are already more advanced are more likely to be planning upgrades. Technology use is positively related to both incremental and major upgrading. For example, contrasting major and minor upgrades (regression 3), we find the probability of undertaking major upgrades to be 43% when there are 16 technologies being used but only 25% when six technologies are being used. Thus plants using more technologies are more likely to be upgrading, thereby further distancing themselves from their counterparts who are using fewer technologies.

In an associated regression (not reported here), technology use was divided into its constituents: quality control, communications and information systems, inventory and distribution, design and engineering, materials handling and preparation, packaging, process control, pre-processing and processing. The largest and most significant coefficients are found for quality control, communications and packaging for the regression contrasting major upgrades against no upgrades; and process control and packaging for the regression contrasting minor upgrades against no upgrades. In other words, plants that use quality control and communication technologies are more likely to be planning a major upgrading as opposed

[23] In light of the lack of significance of most of the variables, ordered logit models were not employed.

Table 12B: Means and Standard Deviations for Dependent and Independent Variables for Technology Upgrades Logistic Regression

Variable	Description	Major vs. None		Minor vs. None		Major vs. Minor	
		Mean	S.D.	Mean	S.D.	Mean	S.D.
1. Dependent variable							
Technological Upgrades	Amount of technology upgrading planned						
REP_LOTS	– major upgrades versus no replacement	0.19	0.39	–	–	–	–
REP_BIT	– minor upgrades versus no replacement	–	–	0.34	0.47	–	–
LOTS_BIT	– major versus minor upgrading	–	–	–	–	0.31	0.46
2. Plant characteristics							
Establishment Size	Employment size						
ESTSIZE1	– 10 - 19 employees	0.27	0.44	0.24	0.43	0.17	0.38
ESTSIZE2	– 20 - 49 employees	0.29	0.45	0.29	0.45	0.26	0.44
ESTSIZE3	– 50 - 99 employees	0.21	0.41	0.20	0.40	0.17	0.38
ESTSIZE4	– 100 - 249 employees	[illegible]	0.37	0.19	0.39	0.22	0.42
ESTSIZE5	– 250 or more employees	0.07	0.26	0.09	0.28	0.18	0.38
Ownership	Country of Control						
FOREIGN	– foreign owned	0.09	0.29	0.11	0.31	0.15	0.36
Production Type	Processing activity						
PRODTYP1	– primary processing	0.44	0.50	0.40	0.49	0.31	0.46
PRODTYP2	– secondary processing	0.23	0.42	0.22	0.42	0.22	0.41
PRODTYP3	– both primary and secondary	0.33	0.47	0.38	0.49	0.47	0.50
Volume of Products	High volume products						
VOLUME	– percentage of shipments tha [illegible]	[illegible]	31.0	61.9	30.5	65.3	27.3
Type of Operation	Type of operation						
BATCH	– batch versus continuous	[illegible]	0.50	0.50	0.50	0.46	0.50
Comprehensive Technology Use							
TECHNOL	Technological intensity	[illegible]	6.65	7.34	6.56	11.10	7.43
Competitive Disadvantage							
DISADV	Technological disadvantage	2.40	2.48	2.37	2.42	2.66	2.37
3. Plant activities							
Business Practices	Business practices						
PRACT_A	– product quality practices	[illegible]	2.21	4.70	2.19	5.32	1.99
PRACT_B	– management practices	2.24	2.22	2.29	2.18	3.09	2.16
PRACT_C	– product and process [illegible]	2.01	2.31	2.11	2.28	3.01	2.43
4. Industry characteristics							
IND_BAKE	Bakery	0.17	0.38	0.16	0.36	0.10	0.30
IND_CERE	Cereals	0.15	0.36	0.14	0.35	0.16	0.37
IND_DAIR	Dairy products	0.10	0.30	0.09	0.29	0.12	0.33
IND_FISH	Fish products	0.15	0.36	0.16	0.37	0.13	0.34
IND_VEGG	Fruit and vegetables	0.07	0.26	0.07	0.26	0.08	0.27
IND_MEAT	Meat	0.18	0.38	0.19	0.39	0.19	0.39
IND_OTHR	Other food products	0.18	0.39	0.19	0.39	0.22	0.42

to no upgrading, while those using process control and packaging are more likely to be planning a minor upgrade than no upgrade at all.

Plants facing more of a disadvantage are also more likely to upgrade. The greatest impact of the disadvantage variable is on the decision to plan a major replacement as opposed to either a minor replacement or no replacement at all. Plants react to being behind. And their reaction is to leapfrog by making major replacements rather than just incremental ones.

We also investigated whether disadvantages in particular areas had greater effects than others (not reported here). Here we found that a significant disadvantage in the key area of processing had a significant effect on making a decision to plan for a major upgrading as opposed to no replacement at all. Suffering a significant disadvantage in the area of packaging also has a significant effect on the decision to engage in major versus minor upgrading.

Even after correcting for technological intensity, size matters. Larger plants are more likely to be making incremental improvements than no improvements at all. The probability of a small establishment choosing incremental over no improvements is 16% compared with about 30% for large establishments. If large plants have any plans for upgrading, they are less likely to make plans for major upgrading but they are more likely to be making incremental improvements. Size gives the advantage of being able to experiment.

There are several reasons why large plants are more likely to expand incrementally. They may have superior information-processing capability, which would give them the capacity to experiment with new technologies in order to evaluate their worth before they make a major commitment.[24] In addition, since they are more likely to be multi-product firms, they may experiment with only some of their production lines, because new technologies will not be applicable across the entire product line.

Few of the other plant characteristics are significantly related to planned upgrading. The one exception is the production-type variable. Plants that combine both primary and secondary processing are more likely to plan for incremental upgrading than no upgrading. They are less inclined to be considering wholesale replacement.

There are no significance differences across industries in the proclivity to upgrade technologies.

[24] See McCardle (1985) for a model that considers the incremental adoption of technology.

Table 12C: Logistic Regression Results for Replacement of Existing with New Technology

Variable	Regression 1	Regression 2	Regression 3
Dependent Variable	REP_LOTS	REP_BIT	LOTS_BIT
INTERCEPT	-3.45 ***	-2.59 ***	-0.75
1. Plant characteristics			
Establishment Size			
ESTSIZE2	0.09	0.43	-0.38
ESTSIZE3	-0.58	0.04	-0.70
ESTSIZE4	-0.33	0.66 *	-1.09 **
ESTSIZE5	0.51	0.90 **	-0.56
Ownership			
FOREIGN	-0.21	0.44	-0.44
Production Type			
PRODTYP2	0.06	0.25	-0.16
PRODTYP3	0.01	0.67 ***	-0.71 **
Volume of Products			
VOLUME	0.01	0.001	0.001
Type of Operation			
BATCH	-0.30	0.11	-0.47 *
Technology Intensity			
TECHNOL	0.12 ***	0.09 ***	0.05 *
Technological Disadvantage			
DISADV	0.13 **	0.05	0.09 *
2. Plant activities			
Business Practices			
PRACT_A	0.01	-0.03	0.05
PRACT_B	0.07	0.04	0.08
PRACT_C	0.01	0.02	-0.05
3. Industry Characteristics			
IND_CERE	0.78	0.52	0.13
IND_DAIR	-0.08	0.42	-0.24
IND_FISH	-0.20	0.20	-0.25
IND_VEGG	0.06	0.19	-0.13
IND_MEAT	-0.18	0.43	-0.67
IND_OTHR	0.40	0.31	-0.03
4. Summary Statistics			
N	541	681	362
χ^2	86.4	93.5	24.0
Log Likelihood	-212	-378	-209

Note: *** significant at the 1% level; ** significant at the 5% level; * significant at the 10% level

Table 12D: Estimated Probability of Replacement of Existing with New Technology

Variable	Regression 1	Regression 2	Regression 3
Dependent Variable	REP_LOTS	REP_BIT	LOTS_BIT
1. Plant characteristics			
Establishment Size			
ESTSIZE1	10	16	39
ESTSIZE2	10	16	39
ESTSIZE3	10	16	39
ESTSIZE4	10	27	17
ESTSIZE5	10	33	39
Ownership			
FOREIGN	10	19	33
NON FOREIGN	10	19	33
Production Type			
PRODTYP1	10	15	42
PRODTYP2	10	15	42
PRODTYP3	10	26	25
Volume of Products			
VOLUME	10	19	33
MEAN +SD	10	19	33
MEAN - SD	10	19	33
Type of Operation			
BATCH	10	19	33
NO BATCH	10	19	39
Technology Intensity			
TECHNOL	10	19	33
MEAN + 5 technologies	19	29	43
MEAN - 5 technologies	5	12	25
Technological Disadvantage			
DISADV	10	19	33
MEAN+SD	13	19	39
MEAN - SD	7	19	28
2. Plant activities			
Business Practices			
PRACT_A	10	19	33
MEAN+SD	10	19	33
MEAN - SD	10	19	33
PRACT_B	10	19	33
MEAN+SD	10	19	33
MEAN - SD	10	19	33
PRACT_C	10	19	33
MEAN+SD	10	19	33
MEAN - SD	10	19	33
3. Industry Characteristics			
IND_BAKE	10	19	33
IND_CERE	10	19	33
IND_DAIR	10	19	33
IND_FISH	10	19	33
IND_VEGG	10	19	33
IND_MEAT	10	19	33
IND_OTHR	10	19	33

Chapter 13 – Conclusion

This study has highlighted the use being made of advanced technologies in the food-processing sector. Its primary focus has been to detail the incidence of use of a large number of highly specific technologies—ranging from machine vision to chromatography. The study provides an assessment of the extent to which the Canadian food-processing industry is on the frontier of technology use.

The results can be organized into broad overviews that elaborate on the pattern of technology use, the type of users (small or large, domestic or foreign), and differences in industry patterns.

13.1 Importance of Advanced Technologies

Advanced technology use has penetrated many areas of the production process in food plants. But the importance is not the same across technologies. Importance of technology has been measured here in three ways: by incidence of technology adoption, by its economic impact, and by its contribution to a plant's international competitiveness.

Our first measure of importance is the degree to which any of the advanced technologies have been adopted in a particular area: processing, process control, quality control, inventory and distribution management systems and communications, materials preparation, pre-processing, packaging, and design and engineering. As measured by incidence of use, the areas of greatest importance for advanced technology use are the key production areas: processing, process control, and management systems and communications. The group next in importance includes packaging, inventory and distribution, quality control—the first two of which involve later stages in the production chain. Then comes pre-processing, and materials preparation—two early stages in the production chain. The area of least importance is design and engineering—a support function in the food-processing industry.

This portrait is somewhat different than the one drawn for the manufacturing sector as a whole (Baldwin and Sabourin 1995), where design and engineering was relatively more important and the central area of fabrication was less important. This can be ascribed to differences in the applicability of different functions. Design and engineering is a key part of mechanical engineering and of many industries outside of food processing, but less important here. Processing and process control play such a central role here because of the importance of quality as an overall strategy to firms in this sector. New advanced processing technologies are part of the thrust to maintain and improve quality. Finally, management systems are found to be central here as elsewhere, thereby confirming earlier work (Baldwin, Diverty and Sabourin 1995) that information collection and assimilation, as well as distribution systems, are at the heart of the soft manufacturing systems that advanced computer-based technologies have spawned.

Since simple rates of incidence may be influenced by the arbitrary choice of technologies included in each category, this study presents an alternate measure of importance—the evaluations of the economic impact of advanced technologies provided by food-processing plant managers. Here too, we find that processing, process control and management systems and communications are among the most important. But quality control now moves to the head of the list, thereby reinforcing the importance of improvements in product quality as the primary objective of technology adoption in the food-processing sector. In the remaining functional areas, the downstream functions—inventory and distribution, and packaging—once more precede the upstream functions—materials handling and pre-processing.

There are a number of exogenous or technical characteristics of plants that are related to technology use. First, plants that produce secondary as opposed to primary products are more likely to utilize advanced technologies in the core area—processing and process control; however, they are also more likely to utilize advanced technologies in both the upstream and downstream areas. High-volume operations are not associated with greater use of the core areas; they are more likely to use an advanced technology in the upstream preparation areas and for process and quality control. Plants that focus on batch operations make greater use of the new management systems and communications technologies to control what is inherently a more heterogeneous production process, but otherwise make less use of most advanced technologies.

Large differences in technology use were also found between small and large plants. These differences are largest for the areas of management systems, design and engineering, and process control. The remaining areas all have differences as well. Some of these can be ascribed to differences in the types of operations found in small and large plants. Small plants are more likely to be doing more batch processing, with fewer high-volume products, and to be concentrating more on primary products. When these factors are taken into account with regression analysis, small firms are still found to use significantly fewer advanced technologies in the three core areas of processing, process control and management systems, as well as in the downstream areas of inventory and distribution and packaging.

The study also found significant differences in technology use between foreign and domestically owned plants. Foreign-controlled plants are more likely to use at least one technology; they are also more likely to use more than 10 advanced technologies and to combine advanced technologies from different areas. They are more likely to use at least one advanced technology in each of the functional areas, with the exception of processing. When other characteristics such as size and type of operations are considered, foreign-owned plants are still found to be greater users of advanced technologies—but not in all areas. What distinguishes foreign-controlled plants from domestically controlled firms is their use of technologies in the area of pre-processing, process control, management systems and communications, and design and engineering.

Economic impact derived from technology adoption was the second metric used to evaluate the importance of advanced technology. It is employed to indicate which of the technologies are seen to have the greatest economic benefits associated with their use.

The reasons for the differences in technology use across small and large plants and between domestic and foreign-owned plants has been a source of interest and concern. They may stem from different barriers originating in differential costs associated with size. Large firms may enjoy scale economies in the acquisition of information regarding new technologies or other advantages in terms of financing costs. On the other hand, the benefits of applying the new technologies in small or domestic plants may be fewer because their operations may be quite different.

This study sheds light on which of these two explanations is most relevant by examining whether managers of plants that have implemented the new advanced technologies have found differences in the impact of the technologies. Finding that there are differences in impact by those who experiment with the new technologies would indicate a major difference in the applicability and therefore in the relevance of the advanced technologies.

After taking into account other characteristics that influence economic impact (such as technology use, volume and batch operations), managers of foreign-controlled plants rarely report a greater economic impact. There is, therefore, weak evidence that foreign-controlled plants do not adopt advanced technologies simply because they find them to be of greater economic benefit. Differences in technology use must therefore be sought in differences in implementation costs.

It is also the case that in many of the areas where there are significant differences between small and large plants in the use of advanced technologies, there are few differences between the two groups in the economic impact derived from the use of these technologies. Thus, when managers in small firms implement advanced technologies, they provide a similar assessment of benefits as managers in large plants. Once more, this indicates that it is the cost rather than the benefit side that primarily determines the differences in the use of advanced technology found in large and small plants.

In this study, we have employed a third metric to evaluate the importance of advanced technologies. This metric examined which technologies are related to competitiveness. Using the managers' evaluations of their technological competitiveness with respect to U.S. competitors, we ascertained that there were a group of technologies whose use determined whether managers assess themselves as more or less competitive. The results reinforce those derived from the other two measures. The key technologies are in the functional areas of processing, process control, and quality control. But pre-processing at the upstream end is also important.

The study has also pointed to the areas in which Canadian plants think they suffer from serious deficiencies in their technology use. Even the most competitive plants consider that they need to make up ground in the areas of inventory and distribution,

design and engineering, as well as in management and communications systems. Thus, it is generally in these peripheral areas that firms recognize their disadvantages. This recognition is also connected with plans to renew and replace technology.

13.2 The Technological Regime

Along with the information on technology use that is provided here, we also investigated the competitive environment of firms, as well as their strategies and business practices. This allows us to better understand the reasons for these patterns of use and ultimately their implications for the food-processing industry.

Since the use of technology is not conducted in a vacuum, it cannot be understood by examining technological incidence alone. Nor can an evaluation be made of just how technologically advanced a plant or an industry is without setting technology use in a broader context. This broader context consists of the environment facing firms and the broad strategic emphasis that firms adopt.

This study has demonstrated how the environment affects technology use. Three major themes have been developed. The first pertains to the manner in which the technology strategy complements the overall strategy of food-processing firms. The second investigates the extent to which practices that are spawned by overall firm objectives interact with a firm's technological competencies. The third examines differences in firms' economic environment and their effect on technology strategy.

13.3 Technology Subsumed within More General Strategies of the Firm

Firms in the food-processing industry face a competitive environment that is dominated by several key challenges—consumers can easily switch products, competitors are able to substitute across suppliers, and new competitors (sometimes from imports) are constantly emerging. As a result, competition is generally intense with respect to both price and quality because of the nature of the product. Firms react by focusing substantial attention on their core markets, both by trying to maintain their cost competitiveness and by stressing quality. Technology use is seen primarily as a way of providing incremental improvements that improve quality and result in cost reductions through increases in productivity.

The stress on quality is continually found in the operations of food-processing firms—both in terms of the strategies pursued and in the technology used. Quality-related business practices are commonly employed. The effect of new technologies is found to be greatest in the area of quality. Quality-related strategies are associated with more technology use in a large number of areas, and their presence enhances the impact of the technologies and the degree to which plant managers rank themselves as competitive with foreign producers.

13.4 Business Strategies: The Interaction between Technology Use and Practices

This study has not only demonstrated how technology strategy complements the main thrust of firms, but it has also shown the importance of specific business practices in facilitating technology acquisition. Technologies are used to accomplish certain purposes: to enhance the quality of products, to develop new products, and to reduce costs.

New machines and processes are only part of what makes up the technological regime. The process of technological change also involves specific business practices that enhance the need for specific technologies. More importantly, some of these practices also enhance the effectiveness of these processes.

This study has examined the incidence of use of business practices in three broad areas: product quality, materials and distribution management, and product and process development. In keeping with the emphasis that is placed on quality by food-processing firms, quality practices were most commonly adopted. These practices complement a large number of different technologies. The use of quality-related business practices is positively associated with the adoption of advanced technology in most functional areas—in every area except packaging. Thus, quality-related practices influence the adoption of advanced technologies in more than just the area of quality control. Similarly, business practices aimed at materials and distribution management are positively associated with technology use across almost all functional groups, although the relationship is not always statistically significant. The product and process development practices are positively and significantly related to technology use in all categories except management systems and communications.

Equally important, these practices enhance the effectiveness of advanced technologies. Firms that have adopted quality management practices indicate that the overall economic impact of technology use was higher in almost all categories. The effect of quality practices then is widely felt across both the core and peripheral functional areas. In the same way, materials and distribution management practices significantly increase the economic impact of communication technologies.

It is also the case that activities related to innovation are of critical importance. The majority of food-processing plants are innovative. Most have introduced process innovations. The introduction of an innovation requires new machines, new techniques and new organizational structures. The technologies that are described here are very much in the forefront of process innovation.

13.5 Technology Use: The Effect of the Industry Environment

In this study, we have recognized that the adoption of technology depends only partially upon the technological opportunity present within an industry. While inherent differences in technological opportunity condition the amount and type of advanced technologies that will be used, there are other forces at work that influence the determinants of technology use. These forces originate in the type and degree of competition that exist in an industry. The intensity of both price and quality competition will vary across industries, with some products experiencing more of both. Differences in competitive pressures should be reflected in differences in the rates of adoption and the types of technologies adopted. Therefore, we examined how these forces differ across industries, and how they are related to the general and technological strategies that were adopted.

The competitive environment is affected by market uncertainty, which in turn is affected by the degree of competition. Market uncertainties stem from the intensity of market competition. Market competition is more intense where companies can switch readily from one supplier to another, where new competitors are constantly arriving in the marketplace and where imports offer a constant alternative source of competition to domestic production. The extent to which advanced technologies are being adopted will also be affected by the rapidity of advances taking place in the industry. Industries where technology is quickly becoming obsolete are also industries where pressures are greater to use new and most likely advanced technologies.

Despite the many differences in the characteristics of the industries studied—in terms of average size of plant, the importance of foreign ownership, capital intensity—the food-processing industries can be divided into several well-defined groups based on firms' evaluations of the intensity of competition that they face from different sources. These consist of 1) bakery and cereals, 2) fish and meat, 3) fruit and vegetables and "other", and 4) dairy. The group indicating that it faced the least uncertainty is the first—bakery and cereals—which shares, along with other industries, the general trait that uncertainty comes from the constant threat of new entrants and from the ease with which competitors can substitute across products. The second group—fish and meat—also indicated that it faced considerable uncertainty from new competitors but added competition from imports as a source of considerable uncertainty. In this sense, therefore, this group can be said to have a more intense competitive environment than the first group. The third group—the fruit and vegetable and "other" industries—faces even more intense import competition than the second group and can be said to face even more uncertainty. These first three groups, taken in order, can be regarded as facing an increasingly uncertain or competitive environment. The fourth category—dairy products—also faces uncertainty from the same basic forces that bakery and cereals face. But rather than imports causing uncertainty, changes in the technological environment associated with obsolescence are at the root of additional uncertainty.

There are broad differences across industries in technological intensity, in economic impact and in the emphasis placed on process innovation, which correspond to these differences in the competitive environment. The groups that face less intense competition tend to be less technologically advanced though this relationship is attenuated by other factors relating to the technological opportunity present in an industry.

The bakery industry falls into the first group with respect to the intensity of competition. Its marketing strategy emphasizes the introduction of new products and it is above average when it comes to new product innovations. However, it is relatively low when it comes to introducing new process innovations, which is consistent with it being one of the least intense users of advanced technologies. The bakery

industry is also least likely to indicate that it received major economic benefits from advanced technology use.

Cereal producers also fall into the first group with respect to uncertainty. They are also in the bottom half of technology users. But some of this simply reflects other characteristics that lead to lower levels of technology use—small average plants and a greater emphasis on batch processes. The multivariate analysis shows that once these characteristics are considered, the cereal industry has above average use for five of the nine advanced technologies.

At the other end of the spectrum with respect to competitive environment are the "other" and the fruit and vegetable industries. These industries are the most intensive technology users and are also more likely to have introduced process innovations than the average. They are also more likely to have realized a positive economic impact from the introduction of all the advanced technologies.

The dairy industry is also classified as having an environment that is more conducive to the adoption of new advanced technologies, in particular because of the amount of technological obsolescence taking place. But it also gives greater emphasis to many of the competitive strategies—competition with respect to price, flexibility in responding to customer needs, quality of products, and new products as well as to strategies in the area of production, management and human resources. Concomitantly, it focuses its attention on acquiring new technologies more than do most other industries. The dairy industry uses more advanced technologies and is more likely to credit these technologies with having an economic impact.

The other two industries—fish and meat—are above bakery and cereals with respect to uncertainty, but below fruit and vegetables with regards to technology use. The meat industry generally gives lower scores than others to all of the competitive strategies—including price, quality, and introduction of new products. The fish industry is less likely to report either product or process innovations. Meat usually exceeds fish with regards to technology use. The meat industry is also more likely to indicate a positive economic impact of technologies while the fish industry is more likely to indicate a negative impact.

In conclusion, this study has demonstrated that evaluations of the importance of advanced technology to Canadian manufacturing establishments need to take into account both incidence (and intensity) of use and the relative competitiveness of an industry. Incidence rates, in isolation, can provide incorrect impressions. We should not equate higher technological incidence with being more competitive when comparing industries. Industries that are the most intense users of advanced technologies do not necessarily feel that they are more technologically competitive than their foreign counterparts. Indeed, exactly the opposite is the case. The dairy industry, which is one of the most intensive users, more frequently ranks itself behind; the fish product industry, which is one of the industries that is the least inclined to use the advanced technologies listed in this report, consistently ranks itself ahead of foreign producers. The meat industry, which is about average in terms of technology use, considers itself to be behind its foreign competitors. Proper evaluations of the importance of technology to the Canadian economy must, therefore, extend beyond uni-dimensional adoption statistics.

Micro-Economic Analysis Division

Survey of Advanced Technology in the Canadian Food Processing Industry

Confidential when completed

Si vous préférez ce questionnaire en français, veuillez cocher ☐

Collected under the authority of the Statistics Act, Revised Statutes of Canada, 1985, Chapter S19.

Survey Objective and Coverage

The objective of this survey is to provide statistics on the technological capabilities of establishments in the food processing industry. Statistics Canada will create a data base combining individual survey responses with existing Statistics Canada data records. These data will be released in aggregate form only so as to maintain the confidentiality of individual business records. The survey will provide a basis for informed decisions on policies and programs concerning technology adoption in the food industry.

Confidentiality

Statistics Canada is prohibited by law from publishing any statistics which would divulge information obtained from the survey that relates to any identifiable business without the previous written consent of that business. Data reported on this questionnaire will be treated in confidence, used for statistical purposes and published in aggregate form only.

Voluntary Survey

While participation in this survey is voluntary, your co-operation is important to ensure that the information collected in this survey is as accurate and as comprehensive as possible.

Questions?

If you require assistance in the completion of this questionnaire or have any quesitons regarding this survey, please phone one of the Statistics Canada regional offices.

In this questionnaire, we refer to several concepts involving the word "firm". **Your firm** refers to the legal entity that owns your plant. **Controlling and/or related firm** refers to the legal entities connected to your firm through ownership links.

Section A: General Questions

A1. Please indicate the countries in which your controlling firm has any of the following operations (percentage distribution of establishments):

COUNTRIES	Production Unit	Research & Development Unit
Canada	99	51
U.S.A.	16	13
Other foreign	10	8

A2. Please indicate the geographic region of the head office of your controlling firm, or in the absence of a controlling firm, the head office of your own firm (percentage distribution of establishments):

REGION	
Canada	89
U.S.A.	8
Other foreign	3

A3. Please indicate which of the following markets are served by the products produced in your plant (percentage distribution of establishments):

MARKETS	
Regional Canadian markets	81
National Canadian markets	51
U.S. markets	47
Other foreign markets	36

A4. Does your plant substantially add to its workforce to meet seasonal peaks? (percentage distribution of establishments):

Yes	No
41	59

A5. Please indicate the maximum number of employees in your plant (including seasonal workers and contract workers) during the last year (percentage distribution of establishments):

NUMBER OF EMPLOYEES	
Less than 20	24
20 to 49	28
50 to 99	20
100 to 249	18
250 or more	10

A6. Is your plant inspected (percentage distribution of establishments):

Federally?	80
Provincially?	53
Locally?	26

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A7. With respect to the products produced in your plant, please rate the importance of the following factors in your business strategy (percentage distribution of establishments):

FACTORS	low 1	2	3	4	high 5	n/a
Markets and Products (goods/services)						
a) Maintaining current products in present markets	1	1	5	17	72	4
b) Introducing new products in present markets	6	5	25	26	32	5
c) Introducing current products in new markets	6	7	24	25	33	6
d) Introducting new products in new markets	15	12	27	18	22	6
Technology						
e) Using technology developed by others	11	11	27	26	17	8
f) Improving existing technologies/ processes	4	5	19	33	34	6
g) Creating new technologies/ processes	13	13	26	23	18	8
h) Accessing R&D facilities	17	18	29	15	12	9
Production						
i) Using new materials	11	15	30	21	15	8
j) Using existing materials more efficiently	3	4	14	31	43	5
k) Increasing line speed	3	5	17	29	40	6
l) Cutting labour costs	3	4	18	23	49	4
m) Implementing computer controlled processes	13	12	24	24	20	8
n) Using high quality suppliers	3	4	14	27	47	5
o) Reducing energy costs	3	9	23	23	39	4
p) Reducing waste disposal costs	5	11	23	21	35	5
Management Practices						
q) Continuously improving quality	1	1	8	26	61	4
r) Entering into strategic alliances/joint ventures	18	16	25	20	13	8
s) Introducing innovative organizational structure (e.g. cross-functional teams)	16	19	26	20	12	8
t) Using information technology	9	13	23	30	17	8

A7. With respect to the products produced in your plant, please rate the importance of the following factors in your business strategy (percentage distribution of establishments): – *(concluded)*

FACTORS	low 1	2	3	4	high 5	n/a
Human Resources Strategy						
u) Continuously training staff	2	8	24	33	29	3
v) Introducing innovative compensation packages	16	20	33	16	8	7
w) Recruiting skilled employees	6	12	30	27	19	6

A8. Please indicate how many firms (whether or not based in Canada) offer products directly competing with yours in Canada (percentage distribution of establishments):

None	1 to 5	6 to 20	Over 20
3	24	36	37

If NONE, skip to B1.

A9. With respect to the products produced in your plant, please score your plant's competitive position relative to your main competitors selling in the Canadian market for each of the factors listed below. (Question is tabulated only for those plants indicating in question A8 that they have competition in Canada) (percentage distribution of establishments):

FACTORS	behind 1	2	same 3	4	ahead 5	don't know
Products and Services						
a) Quality of products	1	2	22	38	30	7
b) Customer services	1	3	23	35	27	11
c) Range of products	3	9	32	27	20	10
d) Flexibility in responding to customers' needs	1	4	19	32	35	9
e) Frequency of introduction of new products	8	17	34	19	11	13
Production Process						
f) Use of advanced manufacturing processes	8	15	37	18	11	13
g) Cost of production	3	11	36	22	10	18
h) Production management	2	7	34	28	13	17
Innovation						
i) Investment in research and development	15	17	25	14	8	20
j) Speed of adoption of new products and technologies	10	14	29	22	8	18

A9. With respect to the products produced in your plant, please score your plant's competitive position relative to your main competitors selling in the Canadian market for each of the factors listed below. (Question is tabulated only for those plants indicating in question A8 that they have competition in Canada) (percentage distribution of establishments): – *(Concluded)*

FACTORS	1 behind	2	3 same	4	5 ahead	don't know
Human Resources						
k) Investment in training	6	16	35	17	6	20
l) Skill levels of employees	3	7	42	25	8	16

Section B: Production

B1. What percentage of the shipments of your plant is accounted for by high volume products? (mean percentage of shipments)

62 percent

B2. Please indicate whether your plant is engaged in (percentage distribution of establishments):

Primary processing	39
OR	
Secondary/value-added/further processing	22
OR	
Both	39

B3. Please provide the approximate number of *major new* product and process innovations you introduced in your plant in the last three years (mean number of innovations):

Product innovations Requiring process innovation	[illegible]
Product innovations Not requiring process innovation	7.2
Process innovations Not associated with product innovation	1.9

B4. Please indicate, irrespective of whether you have a research and development (R&D) program, whether *new products* produced in your plant are introduced by (percentage distribution of establishments):

	Yes	No
a) Purchasing the right to produce products	15	85
b) Adapting, improving or modifying existing products	35	65
c) Developing new products	63	37

B5. Please indicate whether your firm is involved in any of the following R&D activities (percentage distribution of establishments):

ACTIVITIES	In Canada	Outside Canada	Not at all
a) Does your firm do R&D in-house	58	9	41
b) Does your firm do R&D jointly with another firm	25	8	71
c) Does your firm contract out R&D	21	3	78

If you answered NOT AT ALL to all three questions, skip to C1.

B6. Please indicate the *objectives* of your R&D program during the last five years. (Question is tabulated for those establishments indicating in question B5 that they are involved in some R&D activity) (percentage distribution of establishments):

OBJECTIVES	Yes	No
Creation of Original Equipment or Process Technologies		
a) In your firm	65	35
b) With related (sister) firms	23	77
c) With unrelated firms	19	81
d) With public R&D institutions/ universities	22	78
Substantial Adaptation of Technology		
e) In your firm	61	39
f) With related (sister) firms	18	82
g) With unrelated firms	16	84
h) With public R&D institutions/ universities	15	85
Minor Adaptation of Technology		
i) In your firm	80	20
j) With related (sister) firms	26	74
k) With unrelated firms	18	82
l) With public R&D institutions/ universities	16	84
Creation of Original Products		
m) In your firm	85	15
n) With related (sister) firms	30	70
o) With unrelated firms	22	78
p) With public R&D institutions/ universities	18	82
Adaptation of Existing Products		
q) In your firm	88	12
r) With related (sister) firms	32	68
s) With unrelated firms	18	82
t) With public R&D institutions/ universities	16	84

Section C: Business Practices

Product Quality

C1. Are the following *practices* or *techniques*, aimed at enhancing quality, regularly used in your plant? (percentage distribution of establishments)

PRACTICES/TECHNIQUES	Yes	No	N/A
a) Continuous quality improvement (CQI)	77	14	9
b) Benchmarking	47	32	21
c) Acceptance sampling	76	14	10
d) Certification of suppliers	57	27	16
e) Good manufacturing practices (GMP)	81	9	10
f) Hazard analysis critical control points (HACCP)	64	24	12
g) Food safety enhancement program (FSEP)	50	31	19
h) Plant quality certification (e.g. IS09000, American Institute of Baking)	23	53	24
i) Other *(please specify)*	7	34	60

Materials and Distribution Management

C2. Are the following *practices,* aimed at materials management, used by your plant or your firm in conjunction with your plant operations? (percentage distribution of establishments)

PRACTICES	Yes	No	N/A
a) Materials requirement planning (MRP)	49	33	19
b) Manufacturing resource planning (MRP II)	33	44	23
c) Process changeover time reduction	39	38	23
d) Just-in-time inventory control	52	31	17
e) Electronic work order management	20	55	25
f) Electronic data interchange (EDI)	29	47	25
g) Distribution resource planning (DRP)	21	52	27
h) Other *(please specify)*	1	37	62

Product and Process Development

C3. Are the following *product* or *process development techniques* used by your plant or your firm in conjunction with your plant operations? (percentage distribution of establishments)

TECHNIQUES	Yes	No	N/A
a) Rapid prototyping	13	53	33

Product and Process Development

C3. Are the following *product* or *process development techniques* used by your plant or your firm in conjunction with your plant operations? (percentage distribution of establishments) – *(Concluded)*

TECHNIQUES	Yes	No	N/A
b) Quality function deployment	26	44	30
c) Cross-functional design teams	18	49	33
d) Concurrent engineering	16	50	35
e) Computer-aided design	18	47	35
f) Continuous improvement	59	21	20
g) Process benchmarking	34	38	29
h) Process simulation	16	53	31
i) Process value-added analysis	25	45	30
j) Other *(please specify)*	1	37	61

Section D: Operations and Technologies

In this section, we are trying to assess the primary focus of your operations and the advanced technologies you feel are important to your plant.

D1. Please indicate whether the operations in your plant are primarily (percentage distribution of establishments):

53	Continuous	OR	47	Batch
8	Fully automated	OR	92	Semi-automated
40	Flexible manufacturing system	OR	60	Conventional manufacturing system

D2. For this question, please indicate the advanced technologies (owned or leased) that are currently being used for the benefit of your operation (percentage distribution of establishments):

1. Do you use any advanced technologies for **Processing**? If yes, please check off which of the following:

1.1 Thermal Preservation	Yes	No	N/A
a) Aseptic processing/packaging	14	52	34
b) Retortable flexible packages	9	55	36
c) Infra red heating	3	61	37
d) Ohmic heating	1	62	38
e) Microwave or other high frequency heating	4	60	36
f) Other *(please specify)*	5	39	56

D2. For this question, please indicate the advanced technologies (owned or leased) that are currently being used for the benefit of your operation (percentage distribution of establishments): – *(Continued)*

1. Do you use any advanced technologies for **Processing**?
   If yes, please check off which of the following:

1.2 Non-thermal Preservation	Yes	No	N/A
a) Chemical antimicrobials	[illegible]	50	[illegible]
b) Ultrasonic techniques	2	[illegible]	[illegible]
c) High pressure sterilization	9	56	35
d) Deep chilling	25	43	[illegible]
e) Other *(please specify)*	3	42	[illegible]

1.3 Separation, Concentration, Water Removal	Yes	No	N/A
a) Membrane process (e.g. reverse osmosis)	5	57	[illegible]
b) Filter technologies	15	49	[illegible]
c) Centrifugation (e.g. ultracentrifuge)	10	53	[illegible]
d) Ion exchange	3	59	[illegible]
e) Vacuum microwave drying	1	59	39
f) Water activity control	16	47	[illegible]
g) Other *(please specify)*	1	42	57

1.4 Additives/Ingredients	Yes	No	N/A
a) Bio-ingredients (e.g. restructured/ immobolized enzymes)	14	51	[illegible]
b) Microbial cells	8	57	35
c) Other *(please specify)*	2	45	54

1.5 Other	Yes	No	N/A
a) Electrotechnologies (e.g. electrodialysis, electroreduction)	1	59	40
b) Microencapsulation	1	59	40
c) Other *(please specify)*	1	42	58

2. Do you use advanced technology for **Process Control?**
   If yes, please indicate which of the following:

	Yes	No	N/A
a) Automated sensor-based equipment used for inspection/ testing of materials/products	22	51	27
b) Automated statistical process control	14	59	28
c) Machine vision	9	63	28
d) Bar coding for control of product flow in the plant	19	56	26
e) Programmable logic controllers	36	41	23
f) Computerized process control	32	46	23
g) Other *(please specify)*	2	46	52

3. Do you use advanced technology for **Quality Control?**
   If yes, please check off which of the following:

3.1 Process Testing	Yes	No	N/A
a) Chromatography	6	64	31
b) Monoclonal antibodies	3	66	32
c) DNA probes	1	67	32
d) Rapid testing techniques	24	48	28
e) Other *(please specify)*	3	44	53

3.2 Laboratory Testing	Yes	No	N/A
a) Automated	13	61	26
b) Other *(please specify)*	14	41	45

3.3 Simulation	Yes	No	N/A
a) Mathematical modelling of quality/safety	7	62	31
b) Other *(please specify)*	1	45	55

4. Do you use advanced technology for **Inventory and Distribution?**
   If yes, please check off which of the following:

	Yes	No	N/A
a) Bar coding	34	47	19
b) Automated product handling	11	68	21
c) Other *(please specify)*	2	48	50

5. Do you use advanced technology for **Management/Information Systems/ Communications?**

If yes, please check off which of the following:

	Yes	No	N/A
a) Local area network (LAN)	43	42	16
b) Wide area network (WAN)	20	60	20
c) Inter-company computer networks	37	45	18
d) Internet (for marketing or promotional purposes)	27	55	18
e) Internet (for procurement requirements, point-of-sale data, research, hiring, etc.)	27	56	18
f) Other *(please specify)*	1	48	51

6. Do you use advanced technology for **Materials Preparation and Handling?**

If yes, please check off which of the following:

	Yes	No	N/A
a) Integrated electronically controlled machinery (e.g. AGVs)	10	69	21
b) Individual, electronically controlled non-integrated machinery (e.g. robots)	10	69	21
c) Electronic detection of machinery failure	23	57	20
d) Other *(please specify)*	0	47	53

7. Do you use advanced technology in **Pre-processing Activities?**

If yes, please check off which of the following:

7.1 Raw Product Quality Enhancement	Yes	No	N/A
a) Animal stress reduction (e.g. gas stunning)	3	57	40
b) Bran removal before milling wheat	2	56	42
c) Micro component separation	1	57	42
d) Other *(please specify)*	1	40	59

7.2 Raw Product Quality Assessment	Yes	No	N/A
a) Electronic or ultrasonic grading	4	65	31
b) Collagen, colour or P.S.E. probe	3	63	34
c) Near infra red (NIR) analysis	9	61	30
d) Colour assessment/sorting	17	54	29

7. Do you use advanced technology in **Pre-processing Activities?** – *(Concluded)*

If yes, please check off which of the following:

7.2 Raw Product Quality Assessment	Yes	No	N/A
e) Electromechanical defect sorting	4	66	30
f) Rapid testing techniques (e.g. residues, microbial)	19	52	29
g) Other *(please specify)*	3	43	55

8. Do you use advanced technology for **Packaging?**

If yes, please check off which of the following:

	Yes	No	N/A
8.1 Equipment			
a) Non-integrated electronically controlled packaging machinery	29	50	21
b) Integrated electronically controlled packaging machinery	15	62	23
8.2 Preservation			
a) Modified atmosphere	18	55	26
8.3 Advanced Materials			
a) Laminates	18	55	27
b) Active packaging	5	67	28
c) Multi-layer	22	52	26
8.4 Other *(please specify)*	0	45	55

9. Do you use advanced **Design and Engineering Technologies?**

If yes, please check off which of the following:

	Yes	No	N/A
a) Computer aided design (CAD) and/or computer aided engineering (CAE)	18	56	27
b) CAD output used to control manufacturing machines (CAD/CAM)	5	68	27
c) Computer aided simulation and prototypes	3	70	27
d) Digital representation of CAD output used in procurement activities	2	70	28
e) Other *(please specify)*	1	48	52

D3. Of the major technologies listed above, please rate the significance (in terms of economic impact) of the advanced technologies introduced into your plant in the last <u>five</u> years by functional area (Question is tabulated only for those establishments using the technology being considered) (percentage distribution of establishments):

FUNCTIONAL AREAS	Significance: minor 1	2	3	4	major 5	not applicable
a) Processing	5	6	21	25	21	22
b) Process control	6	8	25	27	20	14
c) Quality control	4	7	22	28	30	10
d) Inventory and distribution	6	10	24	27	16	17
e) Management systems and communications	2	7	24	30	16	20
f) Materials handling	5	12	30	24	7	21
g) Pre-processing	9	20	26	15	4	26
h) Packaging	4	8	28	25	19	15
i) Design and engineering	6	15	31	26	14	8

D4. Please indicate your plans to replace existing technologies with advanced technologies at this location over the next <u>three</u> years (percentage distribution of establishments):

a) No plans	29
b) Under consideration	30
c) Minor upgrade (less than 25%)	29
d) Major upgrade (25% to 74%)	12
e) Total replacement (75% or more)	–

D5. Please indicate whether the introduction of *process technologies* is done by (percentage distribution of establishments):

METHODS	In Canada	Outside Canada	Neither
a) Purchasing ready-to-use equipment, documents, blue prints, or designs *from sources*	50	32	41
b) Acquiring and modifying existing technologies *from sources*	44	23	50
c) Adapting technology acquired from unrelated firms *located*	26	20	67
d) Developing new processes by units of your own firm *located*	38	10	59
e) Developing new processes in conjunction with other firms *located*	23	13	72

Section E: Skill Development

E1. Please indicate the educational attainment of the majority of your plant's employees (including seasonal workers and contract workers) (percentage distribution of establishments):

GROUP	Elementary or High School	College or Technical School	University	n/a
a) Production	91	6	1	3
b) Supervisory	49	38	10	4
c) Professionals	21	23	44	12
d) Support staff	45	33	11	11
e) Management	16	33	46	5

E2. Do you provide training (in-house or outside) for your plant employees in the following areas when you implement advanced technology? (percentage distribution of establishments)

	Yes	No
a) Basic language/literacy skills	18	82
b) Basic numeracy skills	18	82
c) Computer literacy	53	47
d) Problem solving skills	40	60
e) Technical skills	63	37
f) Leadership skills	46	54
g) Quality skills	71	29
h) Safety skills	79	21
i) Interpersonal communication skills	39	61
j) Other *(please specify)*	3	97

Section F: Development of New Technologies

Sources of Ideas for New Technologies

F1. Please indicate which of the following sources play an important role in providing ideas for the adoption of new technologies (more than one may apply) (percentage distribution of establishments):

INTERNAL SOURCES	In Canada	Outside Canada	Neither
a) Head office	60	9	37
b) Sister plants	29	10	66
c) Research	41	13	54
d) Development	43	12	54
e) Design	29	11	67

F1. Please indicate which of the following sources play an important role in providing ideas for the adoption of new technologies (more than one may apply) (percentage distribution of establishments): – *(Concluded)*

INTERNAL SOURCES	In Canada	Outside Canada	Neither
f) Production engineering	38	10	58
g) Production staff	64	5	35
h) Technology watch group	16	4	82
i) Sales/Marketing	60	11	38
j) Other	2	1	97

EXTERNAL SOURCES	In Canada	Outside Canada	Neither
k) Industrial research firms	20	7	77
l) Consultants and service firms	41	12	57
m) Publications	47	27	47
n) Trade fairs, conferences	49	35	40
o) Suppliers	62	26	35
p) Customers	58	21	39
q) Other producers in your industry	43	18	53
r) Industry associations	36	16	61
s) Universities	26	7	72
t) Federal or provincial research organizations	27	3	72
u) Other	2	1	98

F2. What importance does your firm give to the systematic collection or monitoring of information on the following? (percentage distribution of establishments)

INFORMATION ON	importance: low 1	2	3	4	high 5	n/a
a) New products	6	9	25	28	24	8
b) New technologies	7	8	28	31	18	8
c) New scientific developments	12	15	30	21	12	11
d) Supply of skilled personnel	7	12	34	25	12	9

Development of New Processes and New Technologies

F3. Please indicate which of the following are used by your firm to *develop* new technologies (percentage distribution of establishments):

SOURCES	In Canada	Outside Canada	Not used
a) Own firm research unit	40	9	56
b) Own firm development group	40	7	57

F3. Please indicate which of the following are used by your firm to *develop* new technologies (percentage distribution of establishments): – *(Concluded)*

SOURCES	In Canada	Outside Canada	Not used
c) Own firm production group	57	5	42
d) Other firms' R&D or production units	17	7	81
e) Head office or related (sister) firms	33	10	62
f) Suppliers	54	16	44
g) Consultants	42	11	56
h) Customers	47	13	52
i) Government/institutes/ universities	30	5	70
j) Other producers in your industry	27	9	70
k) Other *(please specify)*	1	1	99

Acquiring Outside Technologies

F4. Please indicate which of the following sources are used by your firm to *acquire* new technologies (percentage distribution of establishments):

SOURCES	In Canada	Outside Canada	Not used
a) Suppliers	65	27	31
b) Customers	40	14	59
c) Other producers in your industry	37	14	59
d) Head office or related (sister) firms	32	11	63
e) Government/institutes/ universities	26	4	73
f) Other *(please specify)*	1	1	99

F5. Please indicate the method used to *acquire* technologies by source (percentage distribution of establishments):

METHODS	SOURCE: Related Firms	Other Firms	Not applicable
a) Transfer agreements (e.g. licenses, patents, etc.)	10	9	84
b) Transfer of skilled personnel	16	6	80
c) Leasing or purchasing	22	29	55
d) Joint venture/alliances	12	11	81
e) Mergers/acquisitions	9	8	85
f) Reverse engineering	4	3	95
g) Other *(please specify)*	0	0	100

Implementation of New Technologies

F6. Please indicate which of the following personnel are used to *incorporate* new technologies into your plant (percentage distribution of establishments):

OCCUPATION	Own Firm	Other Firms (Including Suppliers)	Not applicable
Professionals			
a) Science professionals	28	14	65
b) Engineering professionals	34	26	51
c) Computing professionals	31	22	56
d) Other (please specify)	6	1	93
Technicians			
e) Science technicians	26	12	67
f) Engineering science technicians	18	16	72
g) Computer assistants	33	18	57
h) Computer equipment operators	35	13	58
i) Electronic equipment operators	26	13	66
j) Plant and machine operators	53	13	43
k) Other *(please specify)*	1	1	99

Section G: Competitive Environment

G1. For the *industry* in which your firm operates, how strongly do you agree or disagree with each of the following statements? (percentage distribution of establishments)

STATEMENTS	1 (disagree)	2	3 (neutral)	4	5 (agree)	does not apply
a) Imports offer substantial competition	15	11	19	21	17	17
b) Consumer demand is easy to predict	13	27	27	19	6	9
c) Competitors actions are easy to predict	12	27	31	16	4	10
d) The arrival of new competitors is a constant threat	7	14	19	28	23	9
e) Products quickly become obsolete	26	24	22	11	5	12
f) Production technology changes rapidly	10	20	25	22	13	10
g) Competitors can easily substitute among suppliers	5	11	22	29	21	11
h) Customers and/or suppliers can become competitors	11	13	18	30	17	12

G2. For the *industry* in which your firm operates, please rate the intensity of competition in the following areas (percentage distribution of establishments):

INTENSITY OF COMPETITION IN	1 (low importance)	2	3	4	5 (high importance)	does not apply
a) Customization of products	4	8	25	32	20	11
b) Price	1	2	9	25	57	6
c) Flexibility in responding to customers' needs	2	4	21	35	31	7
d) Quality of products	1	3	15	34	41	6
e) Customer service	1	4	16	35	38	7
f) Offering a wide range of related products	3	8	26	30	25	8
g) Frequently introducing new/improved products	7	14	28	25	16	10

G3. For the *industry* in which your firm operates, please rate the degree of importance that firms attach to the following areas (percentage distribution of establishments)

DEGREE OF IMPORTANCE ATTACHED TO	1 (low importance)	2	3	4	5 (high importance)	n/a
a) Skilled personnel	2	7	29	37	21	4
b) Use of advanced technologies	7	15	34	29	11	4
c) Research and development	10	15	35	24	12	5
d) Product innovation	7	10	27	34	17	5

G4. How would you compare your production technology with that of your most *significant competitors?* (percentage distribution of establishments)

COMPETITORS	1 (less advanced)	2	3 (about the same)	4	5 (more advanced)	does not apply
a) Other producers in Canada	7	13	42	19	10	10
b) Producers in the U.S.	8	18	30	16	7	22
c) Producers in Europe	9	19	26	9	5	33
d) Other foreign producers	6	10	24	14	6	40

G5. In which of the following functional technology areas do you feel your plant suffers significant technological disadvantages? (percentage distribution of establishments)

FUNCTIONAL AREAS	Yes	No	N/A
a) Processing	31	52	17
b) Process control	33	51	16

G5. In which of the following functional technology areas do you feel your plant suffers significant technological disadvantages? (percentage distribution of establishments) – *(Concluded)*

FUNCTIONAL AREAS	Yes	No	n/a
c) Quality control	18	67	15
d) Inventory and distribution	30	54	16
e) Information systems/ communications	35	49	16
f) Materials handling	25	58	17
g) Pre-processing	16	59	26
h) Packaging	25	55	20
i) Design and engineering	30	44	26

G6. Are you a multi-plant firm? (percentage distribution of establishments)

Yes	No
39	22

If NO, skip TO H1.

G7. How would you compare your production technology with that of <u>other plants also owned by your parent company</u> in Canada and outside of Canada? (Question is tabulated only for multi-plant firms as identified by question G6) (percentage distribution of establishments)

RELATED PLANTS	less advanced 1	2	about the same 3	4	more advanced 5	does not apply
a) In Canada	2	5	18	5	4	66
b) Outside Canada	2	3	10	2	1	82

Section H: Results of Adoption

H1. Please indicate the importance of the following effects as the result of adopting advanced technology (percentage distribution of establishments)

RESULTS	importance: low 1	2	3	4	high 5	n/a
Improvement in Productivity Due to						
a) Reduced labour requirements per unit of output	3	6	20	32	26	13
b) Reduced material consumption per unit of output	11	9	24	24	18	14
c) Reduced capital (plant and equipment) requirements per unit of output	6	10	28	26	17	13
d) Reduced set-up time	7	9	25	26	19	14
e) Reduced rejection rate	8	7	18	27	26	14

H1. Please indicate the importance of the following effects as the result of adopting advanced technology (percentage distribution of establishments) – *(Concluded)*

RESULTS	importance: low 1	2	3	4	high 5	n/a
Product Improvement						
f) Nutrition	11	9	23	25	20	12
g) Taste/texture/ appearance	6	4	17	27	35	12
h) Shelf-life	7	6	17	25	34	12
i) Consumer flexibility/ convenience	5	5	19	31	29	12
Changes in Plant Organization						
j) Firm rationalization of product lines among plants	17	8	29	17	9	21
k) Decreased plant size	27	15	29	7	4	18
l) Increased plant size	14	11	31	17	12	15
m) More product lines	9	8	27	28	14	14
n) Increased production flexibility	5	4	19	38	22	12
o) Higher skill set required	7	7	31	27	13	14
Improvement in Meeting or Exceeding Regulatory Requirements						
p) Workers health and safety	3	3	21	32	32	9
q) Food safety	4	2	12	27	45	10
r) Environmental protection	5	3	22	29	32	9
s) Food composition	7	3	23	28	28	12
Other						
t) Other *(please specify)*	1	0	1	0	0	99

H2. Please indicate whether the introduction of advanced technologies in your plant has increased, decreased or had no effect on the following input requirements (percentage distribution of establishments)

INPUTS	increased	decreased	no effect
Raw Materials			
a) Need for uniform and consistent quality	49	3	48
b) Need for timeliness of delivery	44	3	54
c) Need for specific attributes (composition, size, etc.)	39	3	59

H2. Please indicate whether the *introduction of advanced technologies* in your plant has increased, decreased or had no effect on the following input requirements (percentage distribution of establishments): – *(Concluded)*

INPUTS	increased	decreased	no effect
Raw Materials			
d) Ability to substitute less expensive for more expensive raw materials	24	7	70
e) Need to substitute imported for domestic raw materials	11	7	83
Labour			
f) Ability to substitute less skilled for more skilled personnel	16	24	59
g) Need to substitute more skilled for less skilled personnel	37	9	54

Section I: Impediments to Adoption

I1. Please indicate the importance of the following <u>financial considerations and decisions</u> as *impediments* to technology acquisition (percentage distribution of establishments)

IMPEDIMENTS	importance: low 1	2	3	4	high 5	n/a
Lack of Financial Justification Due to						
a) Small market size	13	12	29	21	15	10
b) Degree of uncertainty associated with evaluation of benefits	8	13	35	22	12	11
c) Cost of buying, leasing or developing new technology/ equipment	6	6	20	31	28	9
d) Costs to develop software	15	12	26	19	16	13
e) Cost of integrating new technology with current technology	9	11	29	26	15	11
f) Additional operating cost	8	8	31	23	19	11
Lack of Financial Resources						
g) Lack of outside financing	24	14	26	13	12	12
h) Lack of cash flow	22	12	16	15	12	13
Other						
i) Other *(please specify)*	2	0	3	0	2	92

I2. Please indicate the importance of the following factors as *impediments* to technology acquisition (percentage distribution of establishments)

IMPEDIMENTS	importance: low 1	2	3	4	high 5	n/a
Management						
a) Lack of procedures to acquire scientific and technological information	20	16	32	15	7	11
b) Low strategic priority	15	17	34	16	8	11
c) Lack of capabilities to evaluate new technology	18	19	31	14	7	11
Human Resources						
d) Shortage of skills	18	19	29	17	7	9
e) Training difficulties	17	19	31	17	6	10
f) Worker resistance	20	22	29	13	7	10
External support services						
g) Lack of technical support from vendors	20	24	29	12	3	12
h) Lack of technological services (e.g. technical and scientific consulting, tests, standards)	20	24	30	10	4	12
Government Policies/Standards/ Regulations						
i) Labour	18	16	32	15	10	10
j) Food Composition	20	17	33	11	8	11
k) Food safety	20	17	25	14	13	11
l) Plant hygiene	20	16	25	13	16	10
m) Environment	19	17	28	14	12	10
Other						
n) Other *(please specify)*	1	0	1	0	0	98

Section J: Role of Government

J1. Please rate the importance to you of the government programs/services that have directly benefited your plant in the last <u>three</u> years (percentage distribution of establishments)

PROGRAMS/SERVICES	importance: low 1	2	3	4	high 5	not used
a) Government training programs	21	12	14	11	5	37
b) Government market information services	21	14	20	6	3	37

J1. Please rate the importance to you of the government programs/services that have directly benefited your plant in the last <u>three</u> years (percentage distribution of establishments): – *(Continued)*

PROGRAMS/SERVICES	low 1	2	3	4	high 5	not used
c) Government export incentives and services	22	10	15	8	4	41
d) Government information and technical assistance programs (e.g. IRAP)	24	9	13	7	5	41
e) Government R&D grants	23	9	12	7	8	42
f) Government investment grants	26	10	10	5	5	45
g) Government strategic technologies programs	24	10	12	3	2	49
h) Government research facilities	23	11	13	6	4	43

J1. Please rate the importance to you of the government programs/services that have directly benefited your plant in the last <u>three</u> years (percentage distribution of establishments): – *(Concluded)*

PROGRAMS/SERVICES	low 1	2	3	4	high 5	not used
i) Tax incentives for machinery and equipment	18	10	16	10	9	37
j) Intellectual property protection	25	11	9	3	3	50
k) Government procurement (purchase of goods and services)	26	11	10	3	3	47
l) R&D tax credit	17	10	14	10	11	39
m) Government hiring program for recent science graduates	24	9	9	5	3	49
n) Other *(please specify)*	4	0	1	0	1	94

Thank you for your co-operation

Do not hesitate to contact the regional office if you have any concerns or questions

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Appendix B: Standard Error Estimates

Micro-Economic Analysis Division

Survey of Advanced Technology in the Canadian Food Processing Industry

Confidential when completed

Si vous préférez ce questionnaire en français, veuillez cocher ☐

Collected under the authority of the Statistics Act, Revised Statutes of Canada, 1985, Chapter S19.

Survey Objective and Coverage

The objective of this survey is to provide statistics on the technological capabilities of establishments in the food processing industry. Statistics Canada will create a data base combining individual survey responses with existing Statistics Canada data records. These data will be released in aggregate form only so as to maintain the confidentiality of individual business records. The survey will provide the basis for informed decisions on policies and programs concerning technology adoption in the food industry.

Voluntary Survey

While participation in this survey is voluntary, your co-operation is important to ensure that the information collected in this survey is as accurate and as comprehensive as possible.

Confidentiality

Statistics Canada is prohibited by law from publishing any statistics which would divulge information obtained from the survey that relates to any identifiable business without the previous written consent of that business. Data reported on this questionnaire will be treated in confidence, used for statistical purposes and published in aggregate form only.

Questions?

If you require assistance in the completion of this questionnaire or have any quesitons regarding this survey, please phone one of the Statistics Canada regional offices.

In this questionnaire, we refer to several concepts involving the word "firm". **Your firm refers** to the legal entity that owns your plant. **Controlling and/or related firm** refers to the legal entities connected to your firm through ownership links.

Section A: General Questions

A1. Please indicate the countries in which your controlling firm has any of the following operations (percentage distribution of establishments):

COUNTRIES	Production Unit	Research & Development Unit
Canada	0.3	1.8
U.S.A.	1.1	1.0
Other foreign	0.8	0.8

A2. Please indicate the geographic region of the head office of your controlling firm, or in the absence of a controlling firm, the head office of your own firm (percentage distribution of establishments):

REGION	
Canada	0.9
U.S.A.	0.8
Other foreign	0.4

A3. Please indicate which of the following markets are served by the products produced in your plant (percentage distribution of establishments):

MARKETS	
Regional Canadian markets	1.4
National Canadian markets	1.7
U.S. markets	1.6
Other foreign markets	1.5

A4. Does your plant substantially add to its workforce to meet seasonal peaks? (percentage distribution of establishments):

Yes	No
1.6	1.6

A5. Please indicate the maximum number of employees in your plant (including seasonal workers and contract workers) during the last year (percentage distribution of establishments):

NUMBER OF EMPLOYEES	
Less than 20	1.2
20 to 49	1.6
50 to 99	1.4
100 to 249	1.2
250 or more	0.8

A6. Is your plant inspected (percentage distribution of establishments):

Federally?	1.4
Provincially?	1.6
Locally?	1.5

4-4800-1.1: 1997-09-05 STC/MES-275-75110

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Canada

A7. With respect to the products produced in your plant, please rate the importance of the following factors in your business strategy (percentage distribution of establishments):

FACTORS	1 (low)	2	3	4	5 (high)	n/a
Markets and Products (goods/services)						
a) Maintaining current products in present markets	0.3	0.3	0.8	1.4	1.6	0.7
b) Introducing new products in present markets	0.9	0.8	1.6	1.6	1.7	0.8
c) Introducing current products in new markets	0.9	0.9	1.6	1.5	1.7	0.8
d) Introducting new products in new markets	1.3	1.2	1.6	1.4	1.5	0.9
Technology						
e) Using technology developed by others	1.1	1.2	1.6	1.5	1.4	1.0
f) Improving existing technologies/ processes	0.7	0.8	1.4	1.7	1.7	0.9
g) Creating new technologies/ processes	1.2	1.2	1.6	1.5	1.4	1.0
h) Accessing R&D facilities	1.3	1.4	1.6	1.3	1.2	1.1
Production						
i) Using new materials	1.2	1.3	1.7	1.4	1.3	1.0
j) Using existing materials more efficiently	0.6	0.7	1.3	1.7	1.8	0.8
k) Increasing line speed	0.5	0.8	1.4	1.6	1.8	0.9
l) Cutting labour costs	0.6	0.7	1.4	1.5	1.8	0.8
m) Implementing computer controlled processes	1.2	1.2	1.6	1.5	1.4	1.0
n) Using high quality suppliers	0.6	0.7	1.3	1.6	1.8	0.8
o) Reducing energy costs	0.6	1.1	1.5	1.5	1.8	0.7
p) Reducing waste disposal costs	0.8	1.2	1.5	1.5	1.7	0.8
Management Practices						
q) Continuously improving quality	0.2	0.4	1.0	1.6	1.8	0.6
r) Entering into strategic alliances/joint ventures	1.4	1.3	1.6	1.4	1.2	1.0
s) Introducing innovative organizational structure (e.g. cross-functional teams)	1.3	1.4	1.6	1.4	1.2	1.0
t) Using information technology	1.1	1.2	1.6	1.6	1.3	1.0

A7. With respect to the products produced in your plant, please rate the importance of the following factors in your business strategy (percentage distribution of establishments): – *(concluded)*

FACTORS	1 (low)	2	3	4	5 (high)	n/a
Human Resources Strategy						
u) Continuously training staff	0.5	1.0	1.6	1.7	1.6	0.7
v) Introducing innovative compensation packages	1.3	1.4	1.7	1.3	1.0	1.0
w) Recruiting skilled employees	0.9	1.2	1.7	1.6	1.4	0.9

A8. Please indicate how many firms (whether or not based in Canada) offer products directly competing with yours in Canada (percentage distribution of establishments):

None	1 to 5	6 to 20	Over 20
0.6	1.5	1.7	1.7

If NONE, skip to B1.

A9. With respect to the products produced in your plant, please score your plant's competitive position relative to your main competitors selling in the Canadian market for each of the factors listed below. (Question is tabulated only for those plants indicating in question A8 that they have competition in Canada) (percentage distribution of establishments):

FACTORS	1 (behind)	2	3 (same)	4	5 (ahead)	don't know
Products and Services						
a) Quality of products	0.3	0.5	1.5	1.7	1.7	1.0
b) Customer services	0.3	0.6	1.5	1.7	1.6	1.1
c) Range of products	0.6	1.0	1.7	1.6	1.4	1.1
d) Flexibility in responding to customers' needs	0.3	0.7	1.4	1.7	1.7	1.1
e) Frequency of introduction of new products	1.0	1.3	1.7	1.4	1.2	1.2
Production Process						
f) Use of advanced manufacturing processes	0.9	1.3	1.8	1.3	1.1	1.2
g) Cost of production	0.6	1.1	1.7	1.5	1.1	1.4
h) Production management	0.5	0.9	1.7	1.6	1.2	1.4
Innovation						
i) Investment in research and development	1.3	1.4	1.6	1.2	1.0	1.4
j) Speed of adoption of new products and technologies	1.1	1.2	1.7	1.5	0.9	1.4

A9. With respect to the products produced in your plant, please score your plant's competitive position relative to your main competitors selling in the Canadian market for each of the factors listed below. (Question is tabulated only for those plants indicating in question A8 that they have competition in Canada) (percentage distribution of establishments) – *(Concluded)*

FACTORS	1 (behind)	2	3 (same)	4	5 (ahead)	don't know
Human Resources						
k) Investment in training	0.9	1.4	1.8	1.4	0.8	1.4
l) Skill levels of employees	0.6	0.9	1.8	1.6	1.0	1.3

Section B: Production

B1. What percentage of the shipments of your plant is accounted for by high volume products? (mean percentage of shipments)

1.1 percent

B2. Please indicate whether your plant is engaged in (percentage distribution of establishments):

Primary processing	1.7
OR Secondary/value-added/further processing	1.5
OR Both	1.7

B3. Please provide the approximate number of *major new* product and process innovations you introduced in your plant in the last three years (mean number of innovations):

Product innovations Requiring process innovation	0.2
Product innovations Not requiring process innovation	1.3
Process innovations Not associated with product innovation	0.2

B4. Please indicate, irrespective of whether you have a research and development (R&D) program, whether *new products* produced in your plant are introduced by (percentage distribution of establishments):

	Yes	No
a) Purchasing the right to produce products	1.2	1.2
b) Adapting, improving or modifying existing products	1.7	1.7
c) Developing new products	1.7	1.7

B5. Please indicate whether your firm is involved in any of the following R&D activities (percentage distribution of establishments):

ACTIVITIES	In Canada	Outside Canada	Not at all
a) Does your firm do R&D in-house	1.7	0.8	1.7
b) Does your firm do R&D jointly with another firm	1.5	0.9	1.6
c) Does your firm contract out R&D	1.4	0.6	1.5

If you answered NOT AT ALL to all three questions, skip to C1.

B6. Please indicate the *objectives* of your R&D program during the last five years. (Question is tabulated for those establishments indicating in question B5 that they are involved in some R&D activity) (percentage distribution of establishments):

OBJECTIVES	Yes	No
Creation of Original Equipment or Process Technologies		
a) In your firm	1.7	1.5
b) With related (sister) firms	1.2	1.8
c) With unrelated firms	1.2	1.8
d) With public R&D institutions/ universities	1.3	1.8
Substantial Adaptation of Technology		
e) In your firm	1.7	1.6
f) With related (sister) firms	1.1	1.8
g) With unrelated firms	1.1	1.8
h) With public R&D institutions/ universities	1.0	1.7
Minor Adaptation of Technology		
i) In your firm	1.7	1.2
j) With related (sister) firms	1.3	1.8
k) With unrelated firms	1.2	1.8
l) With public R&D institutions/ universities	1.1	1.7
Creation of Original Products		
m) In your firm	1.7	1.0
n) With related (sister) firms	1.3	1.8
o) With unrelated firms	1.2	1.8
p) With public R&D institutions/ universities	1.1	1.8
Adaptation of Existing Products		
q) In your firm	1.7	1.0
r) With related (sister) firms	1.4	1.8
s) With unrelated firms	1.2	1.8
t) With public R&D institutions/ universities	1.1	1.8

Section C: Business Practices

Product Quality

C1. Are the following *practices* or *techniques*, aimed at enhancing quality, regularly used in your plant? (percentage distribution of establishments)

PRACTICES/TECHNIQUES	Yes	No	N/A
a) Continuous quality improvement (CQI)	1.6	1.3	1.1
b) Benchmarking	1.7	1.7	1.5
c) Acceptance sampling	1.6	1.3	1.1
d) Certification of suppliers	1.8	1.6	1.4
e) Good manufacturing practices (GMP)	1.5	1.1	1.1
f) Hazard analysis critical control points (HACCP)	1.6	1.5	1.2
g) Food safety enhancement program (FSEP)	1.8	1.7	1.4
h) Plant quality certification (e.g. IS09000, American Institute of Baking)	1.4	1.8	1.6
i) Other *(please specify)*	0.9	1.7	1.8

Materials and Distribution Management

C2. Are the following *practices,* aimed at materials management, used by your plant or your firm in conjunction with your plant operations? (percentage distribution of establishments)

PRACTICES	Yes	No	N/A
a) Materials requirement planning (MRP)	1.8	1.7	1.4
b) Manufacturing resource planning (MRP II)	1.7	1.8	1.5
c) Process changeover time reduction	1.7	1.8	1.6
d) Just-in-time inventory control	1.8	1.7	1.4
e) Electronic work order management	1.3	1.8	1.6
f) Electronic data interchange (EDI)	1.5	1.8	1.6
g) Distribution resource planning (DRP)	1.4	1.8	1.6
h) Other *(please specify)*	0.3	1.7	1.7

Product and Process Development

C3. Are the following *product* or *process development techniques* used by your plant or your firm in conjunction with your plant operations? (percentage distribution of establishments)

TECHNIQUES	Yes	No	N/A
a) Rapid prototyping	1.2	1.8	1.7

Product and Process Development

C3. Are the following *product* or *process development techniques* used by your plant or your firm in conjunction with your plant operations? (percentage distribution of establishments) – *(Concluded)*

TECHNIQUES	Yes	No	N/A
b) Quality function deployment	1.5	1.8	1.7
c) Cross-functional design teams	1.3	1.8	1.7
d) Concurrent engineering	1.2	1.8	1.7
e) Computer-aided design	1.2	1.8	1.7
f) Continuous improvement	1.8	1.5	1.5
g) Process benchmarking	1.6	1.8	1.7
h) Process simulation	1.3	1.8	1.7
i) Process value-added analysis	1.5	1.8	1.7
j) Other *(please specify)*	0.4	1.8	1.8

Section D: Operations and Technologies

In this section, we are trying to assess the primary focus of your operations and the advanced technologies you feel are important to your plant.

D1. Please indicate whether the operations in your plant are primarily (percentage distribution of establishments):

1.8	Continuous	OR	1.8	Batch
0.9	Fully automated	OR	0.9	Semi-automated
1.8	Flexible manufacturing system	OR	1.8	Conventional manufacturing system

D2. For this question, please indicate the advanced technologies (owned or leased) that are currently being used for the benefit of your operation (percentage distribution of establishments):

1. Do you use any advanced technologies for **Processing**? If yes, please check off which of the following:

1.1 Thermal Preservation	Yes	No	N/A
a) Aseptic processing/packaging	1.2	1.8	1.7
b) Retortable flexible packages	1.0	1.8	1.7
c) Infra red heating	0.5	1.8	1.7
d) Ohmic heating	0.3	1.8	1.8
e) Microwave or other high frequency heating	0.7	1.8	1.7
f) Other *(please specify)*	0.8	1.8	1.8

D2. For this question, please indicate the advanced technologies (owned or leased) that are currently being used for the benefit of your operation (percentage distribution of establishments): – *(Continued)*

1. Do you use any advanced technologies for **Processing**?
If yes, please check off which of the following:

1.2 Non-thermal Preservation

	Yes	No	N/A
a) Chemical antimicrobials	1.3	1.8	1.7
b) Ultrasonic techniques	0.4	1.7	1.7
c) High pressure sterilization	1.0	1.8	1.7
d) Deep chilling	1.5	1.8	1.6
e) Other *(please specify)*	0.6	1.8	1.8

1.3 Separation, Concentration, Water Removal

	Yes	No	N/A
a) Membrane process (e.g. reverse osmosis)	0.7	1.8	1.7
b) Filter technologies	1.2	1.8	1.7
c) Centrifugation (e.g. ultracentrifuge)	1.1	1.8	1.7
d) Ion exchange	0.5	1.8	1.8
e) Vacuum microwave drying	0.4	1.8	1.8
f) Water activity control	1.3	1.8	1.7
g) Other *(please specify)*	0.4	1.8	1.8

1.4 Additives/Ingredients

	Yes	No	N/A
a) Bio-ingredients (e.g. restructured/ immobolized enzymes)	1.2	1.8	1.7
b) Microbial cells	0.9	1.8	1.7
c) Other *(please specify)*	0.2	1.8	1.8

1.5 Other

	Yes	No	N/A
a) Electrotechnologies (e.g. electrodialysis, electroreduction)	0.4	1.8	1.8
b) Microencapsulation	0.3	1.8	1.8
c) Other *(please specify)*	0.2	1.8	1.8

2. Do you use advanced technology for **Process Control?**
If yes, please indicate which of the following:

	Yes	No	N/A
a) Automated sensor-based equipment used for inspection/ testing of materials/products	1.5	1.8	1.6
b) Automated statistical process control	0.5	1.8	1.6
c) Machine vision	0.7	1.7	1.6
d) Bar coding for control of product flow in the plant	0.5	1.8	1.6
e) Programmable logic controllers	0.3	1.8	1.5
f) Computerized process control	1.4	1.8	1.5
g) Other *(please specify)*	0.7	1.8	1.8

3. Do you use advanced technology for **Quality Control?**
If yes, please check off which of the following:

3.1 Process Testing

	Yes	No	N/A
a) Chromatography	1.4	1.7	1.6
b) Monoclonal antibodies	1.1	1.7	1.7
c) DNA probes	0.9	1.7	1.7
d) Rapid testing techniques	1.3	1.8	1.6
e) Other *(please specify)*	1.5	1.8	1.8

3.2 Laboratory Testing

	Yes	No	N/A
a) Automated	1.1	1.8	1.6
b) Other *(please specify)*	1.3	1.8	1.8

3.3 Simulation

	Yes	No	N/A
a) Mathematical modelling of quality/safety	0.9	1.7	1.7
b) Other *(please specify)*	0.2	1.8	1.8

4. Do you use advanced technology for **Inventory and Distribution?**
If yes, please check off which of the following:

	Yes	No	N/A
a) Bar coding	1.6	1.8	1.4
b) Automated product handling	1.0	1.7	1.5
c) Other *(please specify)*	0.5	1.8	1.8

5. Do you use advanced technology for **Management/Information Systems/ Communications?**

If yes, please check off which of the following:

	Yes	No	N/A
a) Local area network (LAN)	1.7	1.8	1.3
b) Wide area network (WAN)	1.3	1.7	1.5
c) Inter-company computer networks	1.6	1.8	1.4
d) Internet (for marketing or promotional purposes)	1.6	1.8	1.4
e) Internet (for procurement requirements, point-of-sale data, research, hiring, etc.)	1.6	1.8	1.4
f) Other *(please specify)*	0.4	1.8	1.8

6. Do you use advanced technology for **Materials Preparation and Handling?**

If yes, please check off which of the following:

	Yes	No	N/A
a) Integrated electronically controlled machinery (e.g. AGVs)	1.1	1.7	1.5
b) Individual, electronically controlled non-integrated machinery (e.g. robots)	1.0	1.7	1.5
c) Electronic detection of machinery failure	1.4	1.8	1.5
d) Other *(please specify)*	0.2	1.8	1.8

7. Do you use advanced technology in **Pre-processing Activities?**

If yes, please check off which of the following:

7.1 Raw Product Quality Enhancement	Yes	No	N/A
a) Animal stress reduction (e.g. gas stunning)	0.6	1.8	1.8
b) Bran removal before milling wheat	0.4	1.8	1.8
c) Micro component separation	0.3	1.8	1.8
d) Other *(please specify)*	0.3	1.8	1.8

7.2 Raw Product Quality Assessment	Yes	No	N/A
a) Electronic or ultrasonic grading	0.6	1.7	1.7
b) Collagen, colour or P.S.E. probe	0.6	1.8	1.7
c) Near infra red (NIR) analysis	0.8	1.7	1.7
d) Colour assessment/sorting	1.3	1.8	1.6

7. Do you use advanced technology in **Pre-processing Activities?** – *(Concluded)*

If yes, please check off which of the following:

7.2 Raw Product Quality Assessment	Yes	No	N/A
e) Electromechanical defect sorting	0.6	1.7	1.7
f) Rapid testing techniques (e.g. residues, microbial)	1.3	1.8	1.6
g) Other *(please specify)*	0.6	1.8	1.8

8. Do you use advanced technology for **Packaging?**

If yes, please check off which of the following:

	Yes	No	N/A
8.1 Equipment			
a) Non-integrated electronically controlled packaging machinery	1.5	1.8	1.5
b) Integrated electronically controlled packaging machinery	1.2	1.7	1.5
8.2 Preservation			
a) Modified atmosphere	1.3	1.8	1.6
8.3 Advanced Materials			
a) Laminates	1.3	1.8	1.6
b) Active packaging	0.8	1.7	1.6
c) Multi-layer	1.4	1.8	1.6
8.4 Other *(please specify)*	0.2	1.8	1.8

9. Do you use advanced **Design and Engineering Technologies?**

If yes, please check off which of the following:

	Yes	No	N/A
a) Computer aided design (CAD) and/or computer aided engineering (CAE)	1.2	1.8	1.6
b) CAD output used to control manufacturing machines (CAD/CAM)	0.8	1.7	1.6
c) Computer aided simulation and prototypes	0.5	1.7	1.6
d) Digital representation of CAD output used in procurement activities	0.4	1.7	1.6
e) Other *(please specify)*	0.3	1.8	1.8

D3. Of the major technologies listed above, please rate the significance (in terms of economic impact) of the advanced technologies introduced into your plant in the last five years by functional area (Question is tabulated only for those establishments using the technology being considered) (percentage distribution of establishments):

FUNCTIONAL AREAS	1 (minor)	2	3	4	5 (major)	not applicable
a) Processing	0.8	0.8	1.4	1.4	1.4	1.7
b) Process control	0.9	0.9	1.4	1.3	1.2	1.7
c) Quality control	0.8	0.8	1.3	1.4	1.4	1.7
d) Inventory and distribution	1.0	1.0	1.4	1.3	1.1	1.7
e) Management systems and communications	0.8	0.9	1.4	1.4	1.1	1.7
f) Materials handling	1.0	1.0	1.5	1.3	0.9	1.7
g) Pre-processing	1.0	1.1	1.4	1.1	0.8	1.8
h) Packaging	0.9	0.9	1.4	1.3	1.2	1.7
i) Design and engineering	1.1	1.2	1.4	1.0	0.7	1.8

D4. Please indicate your plans to replace existing technologies with advanced technologies at this location over the next three years (percentage distribution of establishments):

a) No plans	1.6
b) Under consideration	1.7
c) Minor upgrade (less than 25%)	1.6
d) Major upgrade (25% to 74%)	1.2
e) Total replacement (75% or more)	0.2

D5. Please indicate whether the introduction of *process technologies* is done by (percentage distribution of establishments):

METHODS	In Canada	Outside Canada	Neither
a) Purchasing ready-to-use equipment, documents, blue prints, or designs *from sources*	1.8	1.6	1.8
b) Acquiring and modifying existing technologies *from sources*	1.7	1.4	1.8
c) Adapting technology acquired from unrelated firms *located*	1.5	1.4	1.7
d) Developing new processes by units of your own firm *located*	1.7	1.0	1.7
e) Developing new processes in conjunction with other firms *located*	1.5	1.1	1.6

Section E: Skill Development

E1. Please indicate the educational attainment of the majority of your plant's employees (including seasonal workers and contract workers) (percentage distribution of establishments):

GROUP	Elementary or High School	College or Technical School	University	n/a
a) Production	1.3	1.5	0.8	0.3
b) Supervisory	0.7	1.8	1.7	1.1
c) Professionals	1.5	1.5	1.7	1.1
d) Support staff	1.2	1.7	1.7	1.1
e) Management	0.6	1.3	1.7	1.8

E2. Do you provide training (in-house or outside) for your plant employees in the following areas when you implement advanced technology? (percentage distribution of establishments)

	Yes	No
a) Basic language/literacy skills	1.3	1.3
b) Basic numeracy skills	1.4	1.4
c) Computer literacy	1.7	1.7
d) Problem solving skills	1.7	1.7
e) Technical skills	1.7	1.7
f) Leadership skills	1.8	1.8
g) Quality skills	1.7	1.7
h) Safety skills	1.5	1.5
i) Interpersonal communication skills	1.7	1.7
j) Other *(please specify)*	0.5	0.5

Section F: Development of New Technologies

Sources of Ideas for New Technologies

F1. Please indicate which of the following sources play an important role in providing ideas for the adoption of new technologies (more than one may apply) (percentage distribution of establishments):

INTERNAL SOURCES	In Canada	Outside Canada	Neither
a) Head office	1.8	0.9	1.7
b) Sister plants	1.5	0.9	1.6
c) Research	1.7	1.1	1.7
d) Development	1.7	1.1	1.7
e) Design	1.6	1.0	1.6

F1. Please indicate which of the following sources play an important role in providing ideas for the adoption of new technologies (more than one may apply) (percentage distribution of establishments): – *(Concluded)*

INTERNAL SOURCES	In Canada	Outside Canada	Neither
f) Production engineering	1.7	1.0	1.7
g) Production staff	1.7	0.7	1.7
h) Technology watch group	1.3	0.6	1.3
i) Sales/Marketing	1.8	1.1	1.7
j) Other	0.5	0.3	0.6

EXTERNAL SOURCES	In Canada	Outside Canada	Neither
k) Industrial research firms	1.4	0.9	1.5
l) Consultants and service firms	1.7	1.1	1.8
m) Publications	1.8	1.5	1.8
n) Trade fairs, conferences	1.8	1.7	1.8
o) Suppliers	1.7	1.5	1.7
p) Customers	1.8	1.4	1.8
q) Other producers in your industry	1.8	1.3	1.8
r) Industry associations	1.7	1.3	1.7
s) Universities	1.5	0.9	1.5
t) Federal or provincial research organizations	1.6	0.6	1.6
u) Other	0.5	0.3	0.5

F2. What importance does your firm give to the systematic collection or monitoring of information on the following? (percentage distribution of establishments)

INFORMATION ON	importance: low 1	2	3	4	high 5	n/a
a) New products	0.9	1.0	1.6	1.6	1.6	1.0
b) New technologies	0.9	1.0	1.6	1.7	1.4	1.0
c) New scientific developments	1.2	1.3	1.6	1.5	1.2	1.2
d) Supply of skilled personnel	1.0	1.2	1.7	1.5	1.2	1.1

Development of New Processes and New Technologies

F3. Please indicate which of the following are used by your firm to *develop* new technologies (percentage distribution of establishments):

SOURCES	In Canada	Outside Canada	Not used
a) Own firm research unit	1.7	0.9	1.7
b) Own firm development group	1.7	0.8	1.7

F3. Please indicate which of the following are used by your firm to *develop* new technologies (percentage distribution of establishments): – *(Concluded)*

SOURCES	In Canada	Outside Canada	Not used
c) Own firm production group	1.8	0.7	1.8
d) Other firms' R&D or production units	1.3	0.8	1.4
e) Head office or related (sister) firms	1.6	0.9	1.7
f) Suppliers	1.8	1.2	1.8
g) Consultants	1.7	1.0	1.7
h) Customers	1.8	1.2	1.8
i) Government/institutes/ universities	1.6	0.7	1.6
j) Other producers in your industry	1.6	1.0	1.6
k) Other *(please specify)*	0.2	0.2	0.3

Acquiring Outside Technologies

F4. Please indicate which of the following sources are used by your firm to *acquire* new technologies (percentage distribution of establishments):

SOURCES	In Canada	Outside Canada	Not used
a) Suppliers	1.8	1.2	1.7
b) Customers	1.8	1.2	1.8
c) Other producers in your industry	1.8	1.3	1.8
d) Head office or related (sister) firms	1.6	1.0	1.7
e) Government/institutes/ universities	1.5	0.7	1.5
f) Other *(please specify)*	0.3	0.2	0.4

F5. Please indicate the method used to *acquire* technologies by source (percentage distribution of establishments):

METHODS	SOURCE: Related Firms	Other Firms	Not applicable
a) Transfer agreements (e.g. licenses, patents, etc.)	1.0	0.9	1.2
b) Transfer of skilled personnel	1.2	0.8	1.4
c) Leasing or purchasing	1.4	1.6	1.8
d) Joint venture/alliances	1.1	1.0	1.3
e) Mergers/acquisitions	1.0	0.8	1.2
f) Reverse engineering	0.6	0.5	0.8
g) Other *(please specify)*	–	–	0.2

Implementation of New Technologies

F6. Please indicate which of the following personnel are used to *incorporate* new technologies into your plant (percentage distribution of establishments):

OCCUPATION	Own Firm	Other Firms (Including Suppliers)	Not applicable
Professionals			
a) Science professionals	1.5	1.2	1.6
b) Engineering professionals	1.6	1.5	1.7
c) Computing professionals	1.5	1.4	1.7
d) Other (please specify)	1.0	0.3	0.9
Technicians			
e) Science technicians	1.4	1.1	1.6
f) Engineering science technicians	1.2	1.2	1.5
g) Computer assistants	1.6	1.4	1.7
h) Computer equipment operators	1.6	1.2	1.7
i) Electronic equipment operators	1.4	1.2	1.6
j) Plant and machine operators	1.7	1.1	1.8
k) Other *(please specify)*	0.2	0.2	0.3

Section G: Competitive Environment

G1. For the *industry* in which your firm operates, how strongly do you agree or disagree with each of the following statements? (percentage distribution of establishments)

STATEMENTS	1 (disagree)	2	3 (neutral)	4	5 (agree)	does not apply
a) Imports offer substantial competition	0.8	1.2	1.5	1.6	1.5	1.2
b) Consumer demand is easy to predict	1.3	1.1	1.4	1.5	1.4	1.4
c) Competitors actions are easy to predict	1.2	1.6	1.6	1.4	0.8	1.1
d) The arrival of new competitors is a constant threat	1.2	1.6	1.7	1.3	0.7	1.1
e) Products quickly become obsolete	0.9	1.2	1.4	1.6	1.5	1.1
f) Production technology changes rapidly	1.6	1.5	1.5	1.2	0.8	1.2
g) Competitors can easily substitute among suppliers	1.1	1.5	1.5	1.5	1.2	1.2
h) Customers and/or suppliers can become competitors	1.1	1.2	1.4	1.7	1.4	1.2

G2. For the *industry* in which your firm operates, please rate the intensity of competition in the following areas (percentage distribution of establishments):

INTENSITY OF COMPETITION IN	1 (low)	2	3 (importance)	4	5 (high)	does not apply
a) Customization of products	0.4	0.7	1.3	1.7	1.8	1.0
b) Price	0.7	1.0	1.6	1.7	1.5	1.2
c) Flexibility in responding to customers' needs	0.4	0.5	1.1	1.6	1.8	0.9
d) Quality of products	0.6	0.7	1.5	1.7	1.7	1.0
e) Customer service	0.4	0.6	1.3	1.7	1.8	0.9
f) Offering a wide range of related products	0.6	1.0	1.6	1.6	1.6	1.0
g) Frequently introducing new/improved products	0.9	1.3	1.6	1.5	1.3	1.1

G3. For the *industry* in which your firm operates, please rate the degree of importance that firms attach to the following areas (percentage distribution of establishments):

DEGREE OF IMPORTANCE ATTACHED TO	1 (low)	2	3 (importance)	4	5 (high)	n/a
a) Skilled personnel	0.6	1.0	1.7	1.7	1.5	0.7
b) Use of advanced technologies	0.9	1.3	1.7	1.6	1.1	0.8
c) Research and development	1.1	1.3	1.7	1.5	1.2	0.8
d) Product innovation	1.0	1.1	1.6	1.7	1.4	0.8

G4. How would you compare your production technology with that of your most *significant competitors?* (percentage distribution of establishments)

COMPETITORS	1 (less advanced)	2	3 (about the same)	4	5 (more advanced)	does not apply
a) Other producers in Canada	0.9	1.3	1.8	1.4	1.1	1.1
b) Producers in the U.S.	1.0	1.4	1.6	1.3	0.9	1.5
c) Producers in Europe	1.1	1.4	1.6	1.0	0.8	1.7
d) Other foreign producers	0.9	1.1	1.5	1.2	0.9	1.8

G5. In which of the following functional technology areas do you feel your plant suffers significant technological disadvantages? (percentage distribution of establishments)

FUNCTIONAL AREAS	Yes	No	N/A
a) Processing	1.7	1.8	1.4
b) Process control	1.7	1.8	1.4

G5. In which of the following functional technology areas do you feel your plant suffers significant technological disadvantages? (percentage distribution of establishments)

FUNCTIONAL AREAS	Yes	No	n/a
c) Quality control	1.4	1.7	1.3
d) Inventory and distribution	1.7	1.8	1.3
e) Information systems/ communications	1.7	1.8	1.4
f) Materials handling	1.5	1.8	1.4
g) Pre-processing	1.3	1.8	1.6
h) Packaging	1.6	1.8	1.5
i) Design and engineering	1.7	1.8	1.6

G6. Are you a multi-plant firm? (percentage distribution of establishments)

Yes	No
1.6	1.6

If NO, skip TO H1.

G7. How would you compare your production technology with that of <u>other plants also owned by your parent company</u> in Canada and outside of Canada? (Question is tabulated only for multi-plant firms as identified by question G6) (percentage distribution of establishments)

RELATED PLANTS	less advanced 1	2	about the same 3	4	more advanced 5	does not apply
a) In Canada	0.5	0.8	1.3	0.7	0.6	1.5
b) Outside Canada	0.4	0.5	0.9	0.5	0.4	1.2

Section H: Results of Adoption

H1. Please indicate the importance of the following effects as the result of adopting advanced technology (percentage distribution of establishments)

RESULTS	importance: low 1	2	3	4	high 5	n/a
Improvement in Productivity Due to						
a) Reduced labour requirements per unit of output	0.7	0.9	1.4	1.6	1.6	1.2
b) Reduced material consumption per unit of output	1.2	1.1	1.5	1.5	1.4	1.3
c) Reduced capital (plant and equipment) requirements per unit of output	0.9	1.1	1.6	1.5	1.4	1.3
d) Reduced set-up time	0.9	1.0	1.6	1.6	1.4	1.3
e) Reduced rejection rate	1.0	1.0	1.4	1.6	1.6	1.3

H1. Please indicate the importance of the following effects as the result of adopting advanced technology (percentage distribution of establishments) – *(Concluded)*

RESULTS	importance: low 1	2	3	4	high 5	n/a
Product Improvement						
f) Nutrition	1.1	1.0	1.5	1.5	1.5	1.2
g) Taste/texture/ appearance	0.9	0.7	1.4	1.6	1.7	1.2
h) Shelf-life	0.9	0.9	1.3	1.6	1.7	1.2
i) Consumer flexibility/ convenience	0.8	0.7	1.4	1.7	1.7	1.2
Changes in Plant Organization						
j) Firm rationalization of product lines among plants	1.4	1.0	1.6	1.3	1.0	1.5
k) Decreased plant size	1.6	1.3	1.6	0.9	0.7	1.4
l) Increased plant size	1.3	1.1	1.7	1.3	1.2	1.4
m) More product lines	1.0	1.0	1.6	1.6	1.3	1.3
n) Increased production flexibility	0.8	0.7	1.4	1.8	1.5	1.2
o) Higher skill set required	1.0	0.9	1.7	1.6	1.2	1.3
Improvement in Meeting or Exceeding Regulatory Requirements						
p) Workers health and safety	0.7	0.6	1.5	1.7	1.7	1.1
q) Food safety	0.7	0.5	1.2	1.6	1.8	1.1
r) Environmental protection	0.8	0.6	1.5	1.6	1.7	1.1
s) Food composition	0.9	0.7	1.5	1.6	1.6	1.2
Other						
t) Other *(please specify)*	0.3	–	0.3	–	–	0.4

H2. Please indicate whether the introduction of advanced technologies in your plant has increased, decreased or had no effect on the following input requirements (percentage distribution of establishments)

INPUTS	increased	decreased	no effect
Raw Materials			
a) Need for uniform and consistent quality	1.8	0.6	1.8
b) Need for timeliness of delivery	1.8	0.5	1.8
c) Need for specific attributes (composition, size, etc.)	1.7	0.6	1.7

H2. Please indicate whether the *introduction of advanced technologies* in your plant has increased, decreased or had no effect on the following input requirements (percentage distribution of establishments): – *(Concluded)*

INPUTS	increased	decreased	no effect
Raw Materials			
d) Ability to substitute less expensive for more expensive raw materials	1.5	0.9	1.6
e) Need to substitute imported for domestic raw materials	1.1	0.9	1.4
Labour			
f) Ability to substitute less skilled for more skilled personnel	1.3	1.5	1.7
g) Need to substitute more skilled for less skilled personnel	1.7	1.0	1.7

Section I: Impediments to Adoption

I1. Please indicate the importance of the following financial considerations and decisions as *impediments* to technology acquisition (percentage distribution of establishments):

IMPEDIMENTS	importance: low 1	2	3	4	high 5	n/a
Lack of Financial Justification Due to						
a) Small market size	1.2	1.2	1.7	1.5	1.3	1.1
b) Degree of uncertainty associated with evaluation of benefits	1.0	1.2	1.7	1.5	1.2	1.1
c) Cost of buying, leasing or developing new technology/ equipment	0.9	0.8	1.5	1.6	1.6	1.1
d) Costs to develop software	1.3	1.2	1.6	1.4	1.4	1.2
e) Cost of integrating new technology with current technology	1.1	1.1	1.7	1.5	1.3	1.1
f) Additional operating cost	1.0	1.0	1.7	1.5	1.4	1.1
Lack of Financial Resources						
g) Lack of outside financing	1.5	1.2	1.6	1.2	1.2	1.2
h) Lack of cash flow	1.5	1.2	1.6	1.3	1.2	1.2
Other						
i) Other *(please specify)*	0.6	–	0.6	–	0.5	1.0

I2. Please indicate the importance of the following factors as *impediments* to technology acquisition (percentage distribution of establishments):

IMPEDIMENTS	importance: low 1	2	3	4	high 5	n/a
Management						
a) Lack of procedures to acquire scientific and technological information	1.5	1.3	1.7	1.3	0.9	1.2
b) Low strategic priority	1.3	1.3	1.7	1.3	1.0	1.1
c) Lack of capabilities to evaluate new technology	1.4	1.4	1.7	1.2	1.0	1.1
Human Resources						
d) Shortage of skills	1.4	1.4	1.6	1.4	0.9	1.1
e) Training difficulties	1.4	1.4	1.7	1.4	0.8	1.1
f) Worker resistance	1.5	1.5	1.7	1.2	0.9	1.1
External support services						
g) Lack of technical support from vendors	1.5	1.5	1.7	1.1	0.6	1.2
h) Lack of technological services (e.g. technical and scientific consulting, tests, standards)	1.4	1.5	1.7	1.1	0.7	1.2
Government Policies/Standards/ Regulations						
i) Labour	1.4	1.3	1.7	1.3	1.1	1.1
j) Food Composition	1.4	1.3	1.7	1.1	1.0	1.2
k) Food safety	1.4	1.3	1.6	1.3	1.2	1.1
l) Plant hygiene	1.4	1.3	1.6	1.2	1.4	1.1
m) Environment	1.4	1.3	1.6	1.3	1.2	1.1
Other						
n) Other *(please specify)*	0.3	–	0.3	–	–	0.5

Section J: Role of Government

J1. Please rate the importance to you of the government programs/services that have directly benefited your plant in the last <u>three</u> years (percentage distribution of establishments):

PROGRAMS/SERVICES	importance: low 1	2	3	4	high 5	not used
a) Government training programs	1.5	1.1	1.2	1.1	0.8	1.8
b) Government market information services	1.5	1.2	1.4	0.9	0.6	1.8

J1. Please rate the importance to you of the government programs/services that have directly benefited your plant in the last <u>three</u> years (percentage distribution of establishments):
– (Continued)

PROGRAMS/SERVICES	importance: low 1	2	3	4	high 5	not used
c) Government export incentives and services	1.5	1.1	1.2	1.0	0.7	1.8
d) Government information and technical assistance programs (e.g. IRAP)	1.5	1.0	1.2	0.9	0.8	1.8
e) Government R&D grants	1.5	1.0	1.2	0.9	1.0	1.8
f) Government investment grants	1.6	1.0	1.0	0.8	0.8	1.8
g) Government strategic technologies programs	1.5	1.0	1.1	0.6	0.6	1.8
h) Government research facilities	1.5	1.1	1.2	0.8	0.7	1.8

J1. Please rate the importance to you of the government programs/services that have directly benefited your plant in the last <u>three</u> years (percentage distribution of establishments):
– (Concluded)

PROGRAMS/SERVICES	importance: low 1	2	3	4	high 5	not used
i) Tax incentives for machinery and equipment	1.4	1.0	1.3	1.1	1.0	1.8
j) Intellectual property protection	1.6	1.1	1.0	0.6	0.6	1.8
k) Government procurement (purchase of goods and services)	1.6	1.0	1.1	0.6	0.7	1.8
l) R&D tax credit	1.4	1.1	1.2	1.0	1.2	1.8
m) Government hiring program for recent science graduates	1.6	1.0	1.0	0.8	0.7	1.8
n) Other *(please specify)*	0.7	–	0.4	–	0.2	0.9

Thank you for your co-operation

Do not hesitate to contact the regional office if you have any concerns or questions

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References

Äkerblom, M., M. Virtaharju, and A. Leppäahti. 1996. "A Comparison of R&D Surveys, Innovation Surveys, and Patent Statistics Based on Finnish Data." *Innovation, Patents and Technological Strategies.* Paris: OECD.

Baldwin, J. R. 1995. *The Dynamics of Industrial Competition*. Cambridge: Cambridge University Press.

Baldwin, J. R. 1997. *The Importance of Research and Development for Innovation in Small and Large Canadian Manufacturing Firms*. Research Paper No. 107. Ottawa: Statistics Canada.

Baldwin, J. R. and M. Da Pont. 1996. *Innovation in Canadian Manufacturing Enterprises.* Catalogue No. 88-513 XPB. Ottawa: Minister responsible for Statistics Canada.

Baldwin, J. R., B. Diverty and D. Sabourin. 1995. *Technology Use and Industrial Transformation: Empirical Perspectives*. Research Paper 75, Analytical Studies Branch. Ottawa: Statistics Canada.

Baldwin, J. R., T. Gray and J. Johnson. 1995. *Technology Use, Training and Plant Specific Knowledge in Manufacturing Establishments*. Research Paper No. 86, Analytical Studies Branch. Ottawa: Statistics Canada.

Baldwin, J. R., P. Hanel and D. Sabourin. 1999. *Determinants of Innovative Activity in Canadian Manufacturing Firms: The Role of Intellectual Property Rights*. Research Paper No. 120, Analytical Studies Branch. Ottawa: Statistics Canada.

Baldwin, J. R. and J. Johnson. 1995. "Business Strategies in Innovative and Non-Innovative Firms in Canada," *Research Policy,* 25: 785-104.

Baldwin, J. R. and D. Sabourin. 1997. "Technology Adoption: A Comparison between Canada and the United States." *The Canadian Economic Observer* (August): pp 3.1-17. Ottawa: Statistics Canada.

Baldwin, J. R. and D. Sabourin. 1995. *Technology Adoption in Canadian Manufacturing*. Catalogue No. 88-512. Ottawa: Statistics Canada.

Baldwin, J. R., D. Sabourin and M. Rafiquzzaman. 1996. *Benefits and Problems Associated with Technology Adoption in Canadian Manufacturing.* Catalogue No. 88-514-E. Ottawa: Statistics Canada.

Blomstrom, M. and A. Kokko. 1997. *How Foreign Investment Affects Host Countries*. Policy Research Working Paper 1745. Washington: International Economics Department, The World Bank.

Caves, R. E. 1982. *Multinational Enterprise and Economic Analysis*. Cambridge: Cambridge University Press.

Caves, R. E. and M. E. Porter. 1977. "From Entry Barriers to Mobility Barriers." *Quarterly Journal of Economics* 91; 241-61.

Chacko, T. I., J. Wacker and M. M. Asar. 1997. "Technological and Human Resource Management Practices in Addressing Perceived Competitiveness in Agribusiness Firms." *Agribusiness* 13: 93-105.

Cohen, W. and S. Klepper. 1996. "Firm Size and the Nature of Innovation within Industries: The Case of Process and Product R&D." *Review of Economics and Statistics* 78; 232-243.

Cohen W. and R. C. Levin. 1989. "Empirical Studies of Innovation and Market Structure." In *Handbook of Industrial Organization: Vol.2.* Edited by R. Schmalensee and R. D. Willig. Elsevier Science Publishers. B. V.

Dairy Handbook. 1990. Lund, Sweden: Alfa-Laval.

Davidson, V.J. 1997. "Fuzzy Control for Food Processes." In *Computerized Control Systems in the Food Industry*. Edited by G. S. Mittal. New York: Marcel Dekker, Inc.

Fallon, W. K. (Editor).1983. *AMA Management Handbook*. Amacom, American Management Association, Second Edition.

Fey, M.S. 1987. "Food Irradiation: An Innovation in Food Preservation." In *Changing Food Technology*. Edited by M. Kroger and R. Shapiro. Lancaster: Technomic Publishing Co. Inc.

Flood, Robert L. 1993. *Beyond TQM*. Chichester, West Sussex, England: John Wiley and Sons.

Fortin, P. and E. Helpman. 1995. *Endogenous Innovation and Growth: Implications for Canada.* Occasional Paper No 10. Ottawa: Industry Canada.

Getchell, J. R. 1987. "Plant Automation through Technology Integration." In *Changing Food Technology*. Edited by M. Kroger and R. Shapiro. Lancaster: Technomic Publishing Co. Inc.

Gibbons, M. 1995. *Technology and the Economy: A Review of Some Critical Relationships.* Occasional Paper No 12. Ottawa: Industry Canada.

Gordon, J. and J. Wiseman. 1995. "Thriving on Competition." In *Business Quarterly.* London, Ontario: The University of Western Ontario.

Gould, G. W. 1996. "New and Emerging Process Technologies—An Overview." Paper presented at the 89th Annual Convention of the National Food Processors Association. San Francisco, California.

Greig, W. S.. 1984. *Economics and Management of Food Processing*. Westport Connecticut: Avi Publishing Co.

Heldman D. R. and R. W. Hartel. 1997. *Principles of Food Processing*. New York: Chapman and Hall.

Henderson, D. R., C. R. Handy and S.A. Neff (Editors). 1996. *Globalization of the Processed Foods Market.* Agricultural Economic Report No. 742. Washington: Economic Research Service, United States Department of Agriculture.

Hui, Y. H. (Editor-in-Chief). 1992. *Encyclopaedia of Food Science and Technology*. Four Volumes. Toronto: John Wiley and Sons.

Jayanthi, S., B. Kocha and K. K. Sinha. 1996. *Competitive Analysis of U.S. Food Processing Plants*. Working Paper 96-04. St. Paul, Minnesota: The Retail Food Industry Centre, University of Minnesota.

Juran, J. M. 1988. *Juran on Planning for Quality*. New York: The Free Press, Collier Macmillan Canada.

Kane, S. 1996. *Kaizen Strategies for Winning through People*. London: Pitman Publishing.

Kennedy, C. 1991. *Guide to the Management Gurus*. London: Century Business, Random House.

McCardle, K.F. 1985. "Information Acquisition and the Adoption of New Technology." *Management Science* 31:1372-89.

McCorkle, C. O. Jr. (Editor). 1988. *Economics of Food Processing in the United States.* San Diego: Academic Press.

McFetridge, D. G. 1992. *Advanced Technologies in Canada: An Analysis of Recent Evidence on Their Use.* Ottawa: Minister of Supply and Services.

McFetridge, D. G. 1995. *Science and Technology: Perspectives for Public Policy.* Occasional Paper No 9. Ottawa: Industry Canada.

Mittal, G. S. (Editor). 1997a. *Computerized Control Systems in the Food Industry*. New York: Marcel Dekker, Inc.

Mittal, G. S. 1997b. "Process Controls in the Food Industry: Problems and Solutions." In *Computerized Control Systems in the Food Industry*. Edited by G. S. Mittal. New York: Marcel Dekker, Inc.

Mittal, G. S. 1997c. "Computer-Based Instrumentation: Sensors for In-Line Measurements." In *Computerized Control Systems in the Food Industry*. Edited by G. S. Mittal. New York: Marcel Dekker, Inc.

Morrison, C. J. 1997. "Structural Change, Capital Investment and Productivity in the Food Processing Industry." *American Journal of Agricultural Economics* 79: 110-125.

Mowery, D. C. and N. Rosenberg. 1989. *Technology and the Pursuit of Economic Growth.* Cambridge: Cambridge University Press.

Nelson, R. R. 1986. "Evolutionary Modelling Of Economic Change." In *New Developments in Market Structure*. Edited by J.E. Stiglitz and G. F. Mathewson. Cambridge, Massachusetts: The MIT Press.

Newman, H. 1978. "Strategic Groups and Structure-Performance Relationship." *Review of Economics and Statistics* 60:417-27.

Newton, K. 1996. *The Human Factor in Firms Performance: Management Strategies for Productivity and Competitiveness in the Knowledge Based Economy.* Occasional Paper No. 14. Ottawa: Industry Canada.

Nicolai, B. M. 1997. "Computer-Integrated Manufacturing in the Food Industry." In *Computerized Control Systems in the Food Industry*. Edited by Gauri S. Mittal. New York: Marcel Dekker, Inc.

Noori, H. and R. W. Radford (Editors). 1990. *Readings and Cases in the Management of New Technology*. Englewood Cliffs, New Jersey: Prentice Hall.

Noori, H. 1990. *Managing the Dynamics of New Technology.* Englewood Cliffs, New Jersey: Prentice Hall.

Paulson, D. J. and R. L. Wilson. 1987. "Crossflow Membrane Technology: Use in the Food Industry, Recent Innovations." In *Changing Food Technology*. Edited by Manfred Kroger and Ralph Shapiro. Lancaster: Technomic Publishing Co. Inc.

Sabourin, D. and D. Beckstead. 1999. *Technology Adoption in Canadian Manufacturing 1998*. Working Paper ST-99-05. Ottawa: Science, Innovation and Electronic Information Division, Statistics Canada.

Statistics Canada. 1991. "Survey of Manufactures Technology 1989." *Indicators of Science and Technology*, Catalogue 88-002, Vol. 1, No. 4, Ottawa: Statistics Canada.

The American Society of Agricultural Engineers. 1990. *Food Processing Automation*. Proceedings of the 1990 Conference sponsored by the Food and Process Engineering Institute. Lexington, Kentucky.

The Financial Times. 1995. *Handbook of Management*. London: Pitman Publishing.

Vaughan, O. S. 1995. *Implications of Foreign Direct Investment for the Canadian Food and Beverage Manufacturing Industry.* Working Paper No. 2 or 95. Ottawa: Policy Branch, Agriculture and Agri-Food Canada.

Vaughan, O. S., M. Malanoski, D. West and C. Handy. 1994. *Firm Strategies for Assessing Foreign Markets and the Role of Government Policy.* Working Paper No. 5 or 94. Ottawa: Policy Branch, Agriculture and Agri-Food Canada.

West, D. and O. Vaughan. 1995. "Globalization and the Food and Beverage Processing Industry." *Canadian Journal of Agricultural Economics* 43:565-578.

Survey of Advanced Technology in the Canadian Food Processing Industry

This survey examines the adoption of advanced technology in the Canadian food processing industry. Some of the important findings from the survey are:

- Food processing plants are innovative. Nine out of ten plants are using some type of advanced technology with about one in ten using 20 or more.
- Advanced technology is most often found in the key production areas of processing, process control and communications systems.
- Large plants are more likely to adopt advanced technology, particularly processing, process control and communications technologies.
- Foreign-owned plants have higher adoption rates of advanced pre-processing, process control, communications, and design and engineering technologies.
- The industry leaders are the dairy, fruit and vegetable, and 'other' food products sectors, where 'other' includes such high value-added products as TV dinners, frozen pizzas, and snack foods.
- Quality-related practices such as continuous quality improvement and good manufacturing practices accompany the adoption of advanced technology.
- Adoption of advanced technology results in improved food safety.
- Large plants are more likely than small ones to believe that they are technologically competitive.

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